2017-2030 HYDRO ASSET STRATEGY

JUNE 2016

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Executive Summary

The objective of this Hydro Asset Strategy is to invest in equipment refurbishments and replacements to manage the economic, safety and environmental risks of the Federal Columbia River Power System in support of Bonneville Power Administration (BPA)'s mission and vision as well as those of the US Army Corps of Engineers and Bureau of Reclamation.

As in the previous Hydro Asset Strategies, this strategy outlines a multi-year capital program detailing various stages of development. Consistent with BPA's asset management policy, investments are identified through a life cycle cost minimization algorithm that produces optimal replacement dates for over 5,500 assets in the FCRPS. It targets investments primarily in unit reliability at Main Stem Columbia and Headwater / Lower Snake plants in the near term, but shifts focus to more critical auxiliary and operations support equipment in the mid to long term.

Similar to the previous Hydro Asset Strategy, a $300 million per year program level is identified as the recommended level of funding in order to sustain the FCRPS assets for decades to come. The analysis put forth in this strategy shows the benefits of this higher level of funding compared to the resulting program level from the 2014 CIR with allocated headroom and sustain reductions (approximately a $200 million per year program in 2016 dollars).

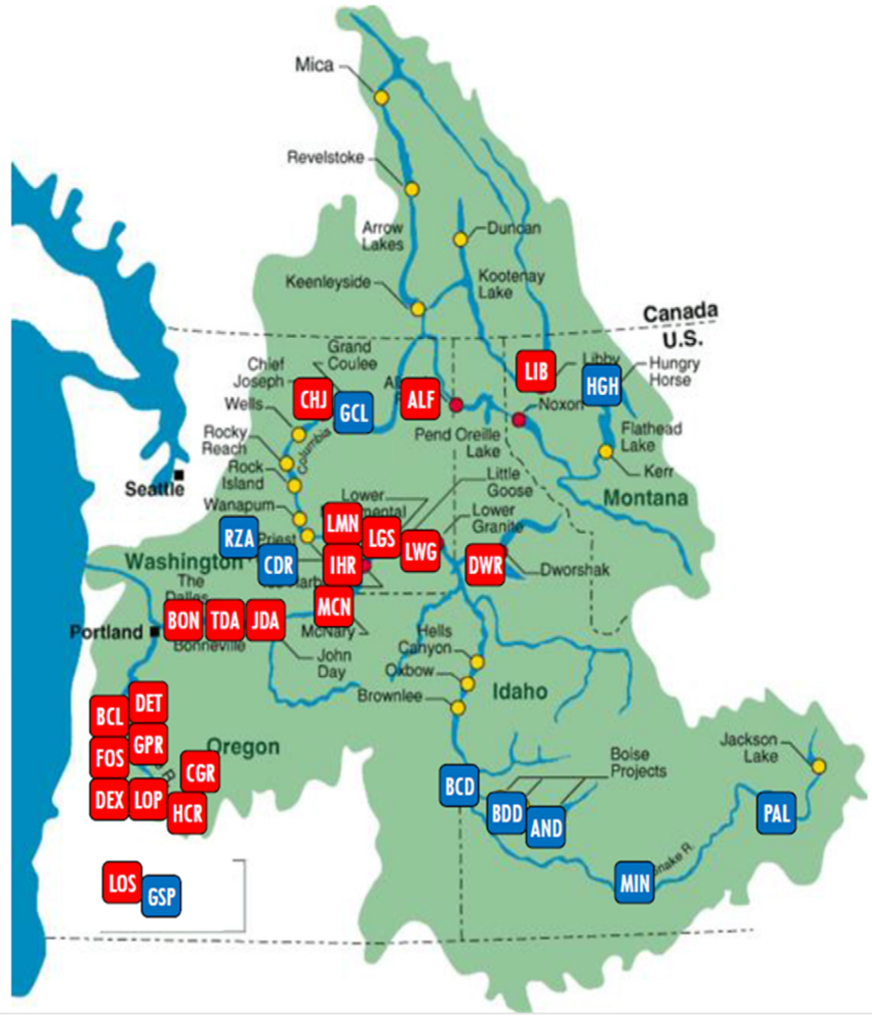
In addition to the reducing lost generation, safety and environmental risk compared to the $200 million Baseline Program, the increased capital investment in the $300 million Recommended Program is also not expected to materially impact rates. Preliminary long-term rates analyses have shown that the Recommended Program will actually result in a slightly lower preference (PF) rate in 2028 than the Baseline Program, primarily due to increased Net Secondary Revenues resulting from higher unit availability. Additionally, the future non-routine expense requirements of a $300 million capital program are also expected to be less than that of a $200 million program due to increased proactive replacements and less reactive repair.

1. ASSET CATEGORY OVERVIEW

The Federal Columbia River Power System (FCRPS) is a partnership between the US Army Corps of Engineers (Corps), the US Bureau of Reclamation (Reclamation), and Bonneville Power Administration (BPA).

FCRPS power related assets are financed through Direct Funding agreements between BPA and the Corps, and BPA and Reclamation. Through Direct Funding, over $500 million is spent annually by the FCRPS on Capital and O&M programs.

The FCRPS has a mandate to provide low cost, reliable power and effective resource stewardship to the Pacific Northwest region. It delivers energy worth $1.9 billion annually (valued at 5-year average Mid-C market prices) to the people of the Pacific Northwest in addition to providing balancing and voltage support as well as protection, mitigation, and enhancement of fish and wildlife. The system also provides an avoided carbon dioxide emission benefit of $1.4 billion annually by displacing fossil-fired generation that would result in emissions in excess of 40 million tons of carbon dioxide per year.



Corps Reclamation

FCRPS Integrated Business Management Model

The FCRPS partnership uses an Integrated Business Management Model (IBMM) to provide a framework for ongoing asset-based planning and management. The IBMM consists of 12 business processes contained within four major areas - Strategic Planning, Asset Planning, Resource Management, and Performance Assessment.

A 3-Agency Steering Committee provides strategic direction to the hydropower program. Joint Operating Committee sub-committees provide direct oversight of specific aspects of the IBMM:

- Capital Investment Program
- Asset Planning
- O&M Program
- Performance Indicators
- River Management
- Hydro Optimization
- Technical Coordination
- Cultural Resources
- Fish and Wildlife

Direction from the three agencies of the FCRPS is to increase the level of efficiency, visibility and accountability for key business processes. The sub-committees are the primary management means for implementing this direction.

The FCRPS is comprised of 31 hydroelectric plants – 21 operated by the Corps and 10 by Reclamation. The FCRPS has an overall capacity of 22,060 MW and, in an average water year, produces 76 million megawatt-hours of electricity.

Within the hydro asset category, the plants are grouped into four strategic classes depending on the role they play in the system. These categories are as follows:

- **Main Stem Columbia**: plants that provide the majority of power, ancillary services, and non-power benefits to the Pacific Northwest.
- **Headwater/Lower Snake**: plants that support services provided by Main Stem Columbia plants.
- **Area Support**: plants that do not support the region as a whole, but provide key power and non-power benefits to a sub-basin, primarily in the Willamette Valley.
- **Local Support**: plants that provide services locally, primarily in Southern Idaho.

FCRPS Hydro System

Plant	ID	Units	MW Capacity	aMW Energy	Strategic Class	Operator
Grand Coulee	GCL	24	6,735	2,497	Main Stem Columbia	Reclamation
Chief Joseph	CHJ	27	2,614	1,387	Main Stem Columbia	Corps
McNary	MCN	14	1,120	575	Main Stem Columbia	Corps
John Day	JDA	16	2,480	991	Main Stem Columbia	Corps
The Dalles	TDA	22	2,052	773	Main Stem Columbia	Corps
Bonneville	BON	18	1,195	513	Main Stem Columbia	Corps
Dworshak	DWR	3	465	214	Headwater/Lower Snake	Corps
Lower Granite	LWG	6	930	272	Headwater/Lower Snake	Corps
Little Goose	LGS	6	930	263	Headwater/Lower Snake	Corps
Lower Monumental	LMN	6	930	278	Headwater/Lower Snake	Corps
Ice Harbor	IHR	6	693	211	Headwater/Lower Snake	Corps
Libby	LIB	5	605	238	Headwater/Lower Snake	Corps
Hungry Horse	HGH	4	428	113	Headwater/Lower Snake	Reclamation
Albeni Falls	ALF	3	49	24	Area Support	Corps
Detroit	DET	2	115	46	Area Support	Corps
Big Cliff	BCL	1	21	13	Area Support	Corps
Green Peter	GPR	2	92	30	Area Support	Corps
Foster	FOS	2	23	12	Area Support	Corps
Lookout Point	LOP	3	138	37	Area Support	Corps
Dexter	DEX	1	17	10	Area Support	Corps
Cougar	CGR	2	28	17	Area Support	Corps
Hills Creek	HCR	2	34	18	Area Support	Corps
Lost Creek	LOS	2	56	36	Area Support	Corps
Palisades	PAL	4	177	74	Area Support	Reclamation
Minidoka	MIN	4	28	22	Local Support	Reclamation
Anderson Ranch	AND	2	40	18	Local Support	Reclamation
Boise Diversion	BDD	3	3	2	Local Support	Reclamation
Black Canyon	BCD	2	10	9	Local Support	Reclamation
Roza	ROZ	1	13	10	Local Support	Reclamation
Chandler	CDR	2	12	9	Local Support	Reclamation
Green Springs	GSP	1	17	6	Local Support	Reclamation
Total		**196**	**22,060**	**8,716**		

Products and Services

Power Generation and Delivery

- Electricity Production (MWh)
- Peak Electricity Capacity (MW)
- Spinning and Non-spinning Reserves
- Load Following
- Voltage Support
- System Restoration (e.g., Black Start)

Non-Power Purposes

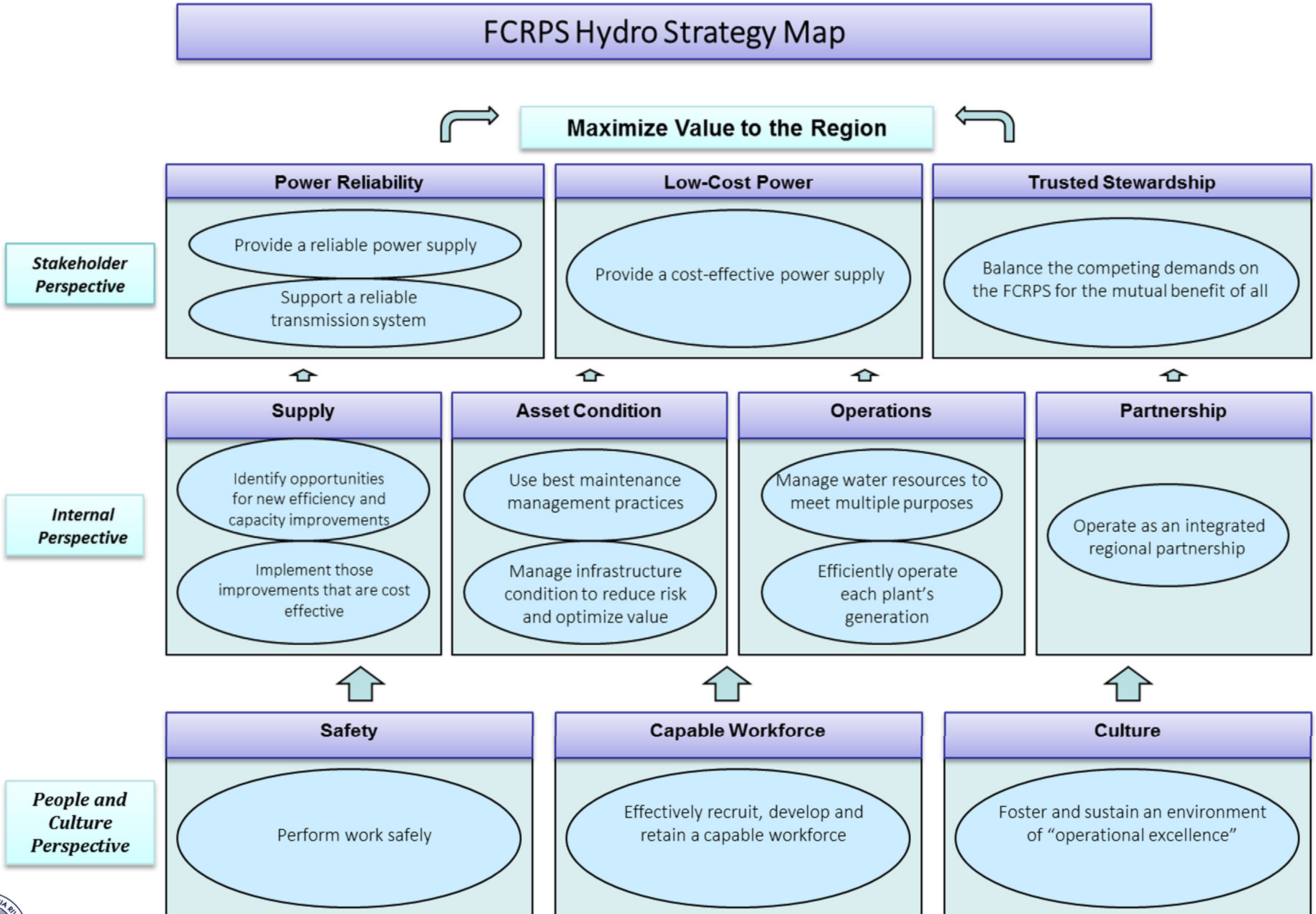
- Flood Damage Reduction – Use reservoir storage to shape natural water flows to reduce impacts to communities, farmland, and industry located along rivers.
- Navigation – Enable an inland waterway through a series of locks on the Columbia and Snake rivers.
- Irrigation – Increase the acreage of arable land in the Pacific Northwest through the storage and diversion of water.
- Recreation – Provide economic and social benefits by facilitating access to reservoirs and by making available parks and recreation areas.
- Municipal and Industrial Water Supply
- Water Quality
- Fish and Wildlife – Protect, mitigate and enhance fish and wildlife, including related spawning grounds and habitat, of the Columbia River and its tributaries.

Value of Strategic Classes by Purpose

Purpose	Main Stem Columbia	Headwater/Lower Snake	Area Support	Local Support
Power	Provides 76% of energy and capacity, and 30% of storage from the FCRPS. Provides nearly all the reserves and other ancillary services for supporting the 500 kV grid.	Provides 20% of energy and capacity, and 50% of storage from the FCRPS. Provides supplementary ancillary services for supporting the 500 kV grid.	Provides 3% of energy and capacity, and 18% of storage from the FCRPS. Provides voltage support to specific areas of the regional transmission grid	Provides 1% of energy and capacity, and 2% of storage from the FCRPS. Provides limited voltage support to local areas of the Pacific Northwest.
Flood Damage Reduction	Seasonal flood reduction and water management storage affecting significant parts of the Columbia River basin.	Seasonal flood reduction and water management storage affecting significant parts of the Columbia River basin.	Provides flood reduction benefits primarily in the Willamette Valley, but does not contribute significantly to the flood reduction capability of the overall Columbia River basin.	Provides flood reduction benefits in a local area
Navigation	Provides navigation for the lower Columbia River from below Cascade Locks to the Tri-Cities	Provides navigation for the lower Snake River from the Tri-Cities to Lewiston, ID	None	None
Irrigation	Primary source of irrigation for the Columbia River Basin	None	None	Primary source of irrigation within a specific region
Recreation	Significant recreation for boating and camping. Includes several “destination” recreation sites and numerous local sites.	Major recreation for boating and camping. Includes several “destination” and local sites.	Major recreation for boating and camping. Includes several “destination” and local sites.	Some boating and camping at local sites.
Fish and Wildlife	Significant regional role in management of reservoir lands, fish passage, and wildlife mitigation.	Significant role in management of reservoir lands, fish passage, flow augmentation and wildlife mitigation.	Provides a role in managing fish and wildlife primarily in the Oregon Cascades.	Localized role in fish and wildlife mitigation.

2. ASSET STRATEGY SCOPE, DIRECTION AND OBJECTIVES

FCRPS Hydro Strategy Map



FCRPS Hydro Strategy Logic and Scope

The FCRPS Hydro Strategy focuses on three goals:

- Low Cost Power;
- Power Reliability; and
- Trusted Stewardship

The strategy is implemented through a set of Direct Funding Agreements to:

- Ensure that life safety and environmental requirements are met;
- Meet FCRPS commitments for fish and wildlife and cultural resource programs;
- Meet BPA's business continuity needs for a reliable supply of low-cost generation by ensuring power generating assets are properly operated, inspected, and maintained;
- Mitigate the risk of power generation component failures by replacing or refurbishing equipment and purchasing spares when warranted;
- Increase the efficiency and/or capability of power facilities where economically feasible; and
- Fund a portion of high priority multi-purpose projects, in accordance with BPA's direct funding agreements with the Corps of Engineers and Bureau of Reclamation.

With this in mind, the 2018 strategy includes:

- Direct Funded O&M Program,
- Direct Funded Investment Program, and
- Appropriations reimbursed by BPA.

Program funding needs are established through the IBMM model, as described in Section 1.

- In general, the **O&M Program** reflects core funding for maintenance, operations, and minor equipment replacements, and is largely driven by the staffing needs of each facility.
- In contrast, the **Capital Program** is comprised primarily of large, discrete investment needs for equipment replacement or refurbishment, largely driven by condition and risk.

The Capital Program funding proposals presented within this strategy focus on the 15-year period, FY2016 – FY2030. Investments target electrical and mechanical systems, with less of a focus on civil features for dam safety, which are typically funded through appropriations, a share of which is reimbursed by BPA.

- Reinvestment costs in dam safety have been relatively low for the history of the FCRPS. Civil features are long-lived and rebuilding and/or replacement needs are negligible for the first 50 or more years of plant life. However, at some point significant reinvestment in civil works for dam safety is needed to extend useful asset life.
- For the focus period of this strategy, the exclusion of costs for dam safety civil features is not expected to materially affect the funding need forecast. However, as the hydro system continues to age, anticipating funding needs for dam safety will require more explicit attention in future strategies.

Relative Cost of Unavailability. The criticality of a hydro asset is based largely on the quantity of energy produced, particularly at peak periods, and the financial impact of a loss of generation. Assets in the Main Stem Columbia and Headwater/Lower Snake strategic classes provide more than 96 percent of energy and capacity for the system.

Five plants – Grand Coulee, McNary, Chief Joseph, John Day and Dworshak – are considered particularly critical to the power system based on the significant financial impact of a generating unit outage at these facilities.

The figure on the following page groups FCRPS hydro plants by their strategic class and relative cost of unavailability (RCU) to the power system. The relative cost of unavailability is the annual cost of replacing lost generation from the least-used generating unit, or first 20 percent of lost plant availability, whichever is larger. No costs are included for replacing lost capacity, ancillary services, or non-power benefits.

Major RCU is up to $10 million per year, and is based on BPA's long-term forward price forecast and average water conditions. Extreme RCU ranges from $10 to $40 million annually, while Severe RCU exceeds $40 million per year. No value is included for avoided CO_2 emissions.

The figure shows that Grand Coulee, McNary, Chief Joseph, John Day and Dworshak are the plants with the highest RCU.

FCRPS Hydro Plant Classification

Relative Cost of Unavailability (RCU)	Local Support	Area Support	Headwater/ Lower Snake	Main Stem Columbia
Severe >$40m/yr				CHJ GCL MCN
Extreme $10 - $40m/yr			DWR	JDA
Major <$10m/yr	AND, BCD BDD, MIN, ROZ, CDR, GSP	BCL, DEX, LOS, DET, GPR, LOP, HCR, CGR, FOS, ALF, PAL	LIB, HGH, IHR, LGS, LWG, LMN	BON TDA

Strengths of the FCRPS Hydro System

Low, Stable Costs: The FCRPS hydro system provides a low and relatively stable cost of power, with a cost of generation of less than $10 per megawatt-hour. Average annual generation is 76 million megawatt-hours. Costs are increasing over time due to increases in labor rates and investments to repair and replace aging equipment as well as additional requirements related to reliability, security and oil. However, the program identified in this strategy is still expected to keep the levelized cost of generation under $10 per megawatt-hour

Storage and Peaking: The FCRPS hydro system has a maximum useable storage of 10.5 ksfd, providing flood damage reduction, irrigation, fish and wildlife benefits, recreation opportunities, and increased value from the power system by storing water to be used when it is more valuable for generation.

Ancillary Services and Resource Integration: The hydro system provides all voltage support, load following, spinning and non-spinning reserves, and other ancillary services for BPA's transmission system. Hydropower also serves as the primary mechanism for integrating wind resources into the power system.

Climatic Risk: FCRPS hydro generation produces zero carbon dioxide emissions, which are recognized as a primary contributor affecting climate change. Hydro generation both lessens climate change effects by reducing emissions that otherwise would be produced by alternative generation sources and remains cost effective within resulting weather variations that may influence water supply. The social cost of carbon emissions resulting from replacing hydro generation with carbon-emitting replacement power due to hydro unit failures is considered in the optimal replacement dates identified in this strategy.

Energy Payback: Energy payback ratio is a comparison of the energy produced by a system divided by the energy consumed to build and operate the system over its useful life. Hydropower, with an energy payback ratio of 205, has the highest ratio of all generation sources. By comparison, the ratio for wind is 23 (without backup), nuclear fission (16), coal (11), and natural gas (4).

Skilled Workforce: The FCRPS has a dedicated and skilled workforce with a keen understanding of the operations and maintenance needs of the hydro system.

Weaknesses of the FCRPS Hydro System

Weather and Water Supply: Changing weather conditions and the resulting changes in water supply create a degree of uncertainty in hydropower production different than that from thermal generation alternatives. Between years, the difference in energy production from FCRPS hydro can be several thousand average megawatts. This presents unique challenges to managing the entire portfolio of power supply needed to meet the demands of BPA customers.

Environmental Costs: The FCRPS faces high environmental costs for mitigating the impact of developing the Columbia River Basin. The direct funded program costs considered in this strategy include $34 million per year for maintaining fish passage equipment and hatcheries. In addition to costs included in this strategy, environmental costs total more than $350 million per year for BPA's direct fish and wildlife program and the Corps' appropriated program to construct additional fish rearing and passage facilities. Indirect costs for changes in system operations now total several hundred million dollars per year. Replacing turbine runners with new fish friendly designs has been identified as a potential measure to reduce the maintenance and replacement burden of aging fish screens while gaining efficiency and improving reliability of the units.

Aging Workforce: The power industry as a whole is now facing a retirement eligibility bubble that poses significant risk to maintaining the workforce needed to operate and maintain facilities effectively. A large percentage of personnel working on-site at FCRPS hydro plants are eligible for retirement within five years.

Aging Infrastructure: The hydro system is aging, approaching an average age of 50 years. The oldest plant in the system is Minidoka, with an in-service date of 1911. Bonneville Dam is the oldest Main Stem Columbia plant, with an in-service date of 1938. While many more years of valuable production can be expected from the hydro system, it faces significant challenges associated with maintenance and replacement demands to preserve this value.

Politically Unpopular: In Canada, Europe, Australia and New Zealand, hydropower is generally seen as a clean and reliable source of renewable energy. In the United States, hydropower is often perceived more negatively despite the trends to look at hydropower as a renewable resource.

3. CURRENT PERFORMANCE, CONDITION AND RISK

- The Corps and Reclamation Expense program funds approximately 1,600 employees. Costs for salaries, benefits, materials and supplies are 70 to 75 percent of the budget.
- The largest portion of the O&M Program funds plant operators, electricians, mechanics, and other skilled tradespeople performing routine operations and maintenance of equipment at FCRPS facilities.
- The O&M program includes funding for mitigation activities:
  - About 15 percent of O&M program costs are **Fish and Wildlife O&M** for fish screens, hatcheries, fish bypass facilities, trap and transport, etc.
  - About 2 percent of O&M program costs are for the **FCRPS Cultural Resource** program and mitigation activities associated with Section 106 compliance
- Other programs include Dam Safety, Clean Water, Water Management, Employee Safety, Engineering, Contracting, Physical and Cyber Security, Reliability Compliance and other Support Services.

Current Performance, Low Cost Power

Operations and Maintenance Program Overview – Non-Routine Extraordinary Maintenance

- About 17 percent of O&M program costs are for Non-Routine Extraordinary Maintenance (NREX), the large infrequent maintenance and repair activities associated with failed or failing equipment, as well as the Grand Coulee Third Powerplant Overhaul.
- As infrastructure has gotten older, nearing its design life, NREX needs have increased. Significant undistributed reductions in both the '12-'13 and '14-'15 rate cases were absorbed by the NREX program, causing many major projects to be deferred. That bow wave of critical work is now being addressed.
- NREX needs span all types of assets: unit reliability, water control, cranes, fire suppression systems, critical spare parts, and more
- Examples of significant ongoing or upcoming work include The Grand Coulee Third Powerplant mechanical overhaul, Kaplan turbine inspections and blade pinning at John Day and the Lower Snake dams, cavitation repair, headgate and spillway gate refurbishment, and penstock gates and coatings.

The Capital Program includes:

- Reliability driven replacements of capital components with a focus on powertrain and critical ancillary equipment;
- Investment in environmental and safety improvements;
- Economic opportunity investments to existing assets that are undertaken to improve system performance (e.g., turbine runner replacements to improve efficiency); and,
- Investments in new assets at existing facilities (e.g., adding a new generating unit), also based on economic opportunity.

Current Performance, Low Cost Power

Cost of Generation

Project Name	Annual Appropriations Interest[1]	Interest on Non-Federal Debt Associated with Fed Hydro Debt[1]	Interest on Outstanding Bonds[1]	Interest on PrePay[1]	FY2015 Interest[1]	Total O&M[1]	Depreciation[1]	FY2015 Total Cost[1]	Total Cost %	Net Generation (GWh)	O&M Expense ($/MWh)	Total Cost of Generation ($/MWh)	Capacity
Albeni Falls	208	843	460	233	1,744	6,983	903	9,630	1.66%	208	33.58	46.31	49
Anderson Ranch	222	483	264	133	1,103	4,200	323	5,625	0.95%	159	26.46	35.44	40
Big Cliff	16	113	61	31	221	851	203	1,275	0.22%	111	7.66	11.47	21
Black Canyon	56	121	66	33	276	1,050	81	1,406	0.24%	80	13.15	17.61	10
Boise Diversion	17	36	20	10	83	315	24	422	0.07%	15	20.55	27.52	3
Bonneville	34,546	4,422	2,415	1,221	42,603	26,056	15,330	83,989	8.69%	4,945	5.27	16.98	1,195
Chandler	22	140	77	39	278	1,201	114	1,592	0.28%	76	[illegible]	21.06	12
Chief Joseph	16,243	4,399	2,402	1,215	24,259	31,111	10,064	65,435	8.65%	10,811	[illegible]	6.05	2,614
Cougar	765	238	130	66	1,199	1,542	688	3,429	0.47%	150	10.27	22.83	28
Detroit	85	617	337	170	1,209	4,660	1,112	6,981	1.21%	407	11.46	17.16	115
Dexter	81	93	51	26	251	693	181	1,126	0.18%	87	8.01	13.01	17
Dworshak	894	1,729	944	477	4,046	11,995	4,191	20,232	3.40%	1,826	6.57	11.08	465
Foster	7	128	70	35	239	1,029	168	1,436	0.25%	109	9.43	13.17	23
Grand Coulee	34,986	13,975	7,632	3,858	60,451	109,132	21,669	191,252	27.48%	21,208	5.15	9.02	2,614
Green Peter	26	511	279	141	958	4,115	670	5,742	1.01%	261	15.78	22.02	92
Green Springs	655	135	73	37	900	1,113	146	2,159	0.26%	51	21.66	42.00	17
Hills Creek	171	151	82	42	446	993	417	1,856	0.30%	168	5.92	11.07	34
Hungry Horse	833	860	470	237	2,400	6,141	1,909	10,450	1.69%	1,026	5.99	10.18	428
Ice Harbor	6,422	1,401	765	387	8,975	10,447	2,666	22,088	2.75%	2,043	5.11	10.81	693
John Day	1,648	3,692	2,017	1,020	8,376	27,080	7,481	42,937	7.26%	9,179	2.95	4.68	2,480
Libby	12,811	1,664	909	459	15,843	9,558	6,014	31,415	3.27%	2,100	4.55	14.96	605
Little Goose	8,544	1,614	881	446	11,485	11,889	3,216	26,589	3.17%	2,474	4.81	10.75	930
Lookout Point	659	758	414	209	2,041	5,628	1,471	9,140	1.49%	322	17.48	28.39	138
Lost Creek	1,062	288	157	80	1,587	2,271	428	4,286	0.57%	309	7.34	13.85	56
Lower Granite	7,915	2,212	1,208	611	11,946	15,327	5,379	32,652	4.35%	2,427	6.31	13.45	930
Lower Monumental	7,796	1,595	871	440	10,701	11,261	3,665	25,628	3.14%	2,560	4.40	10.01	930
McNary	771	3,121	1,705	862	6,459	22,996	6,221	35,675	6.14%	5,446	4.22	6.55	1,120
Minidoka	498	171	94	47	810	1,356	246	2,412	0.34%	196	6.93	12.32	28
Palisades	3,145	1,082	591	299	5,118	8,575	1,557	15,249	2.13%	647	13.26	23.57	177
Roza	22	140	77	39	278	1,201	114	1,592	0.28%	85	14.09	18.69	13
The Dalles	2,403	3,060	1,671	845	7,979	22,156	6,485	36,619	6.02%	6,790	3.26	5.39	2,052
Total	**143,529**	**49,793**	**27,193**	**13,748**	**234,262**	**362,922**	**103,134**	**700,319**	**97.91%**	**76,276**	**4.76**	**9.18**	**17,929**

/1 $000s
*Excludes CRFM

The FCRPS benchmarks its hydro program annually in order to identify areas of best practice and the potential for performance improvement.

Costs benchmarked include Corps and Reclamation costs for hydropower, recreation, and joint-use purposes, and BPA costs for program coordination, planning, scheduling, generation dispatch, and fish and wildlife mitigation.

Because Direct Funding program costs are only a subset of all costs benchmarked, one-to-one comparisons cannot be made between the Direct Funding program and the benchmarks. However, the benchmarking results do provide useful information on the allocation of costs within the program and how FCRPS costs compare with those of its peers.

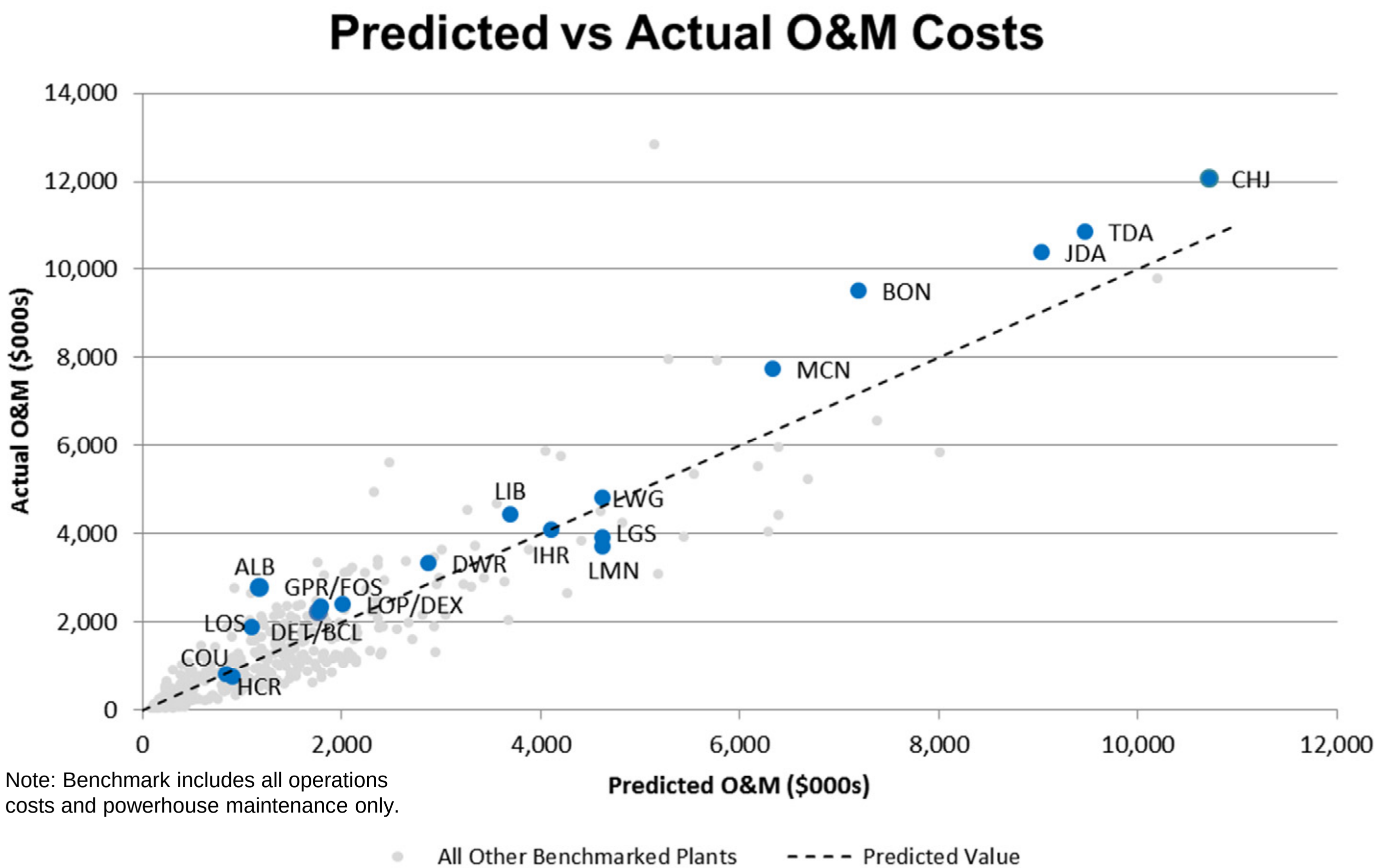
EUCG uses the following cost categories for the sake of cost comparison between utilities:

- Operations (O) includes facility operations and all operations planning
- Maintenance (M) includes all facility maintenance
- Administration (A) includes IT, Finance, HR, telecom, asset management, and more
- Environmental/Regulatory (ER) includes F&W, Recreation, and Cultural Resources
- Land and Water Fees (LW) includes rentals or fees for use of land or water
- Investment (I) includes non-routine expense and capital reinvestment

One of the issues present in benchmarking is controlling for the economies of scale inherent in the comparison of plants with varying sizes. The classic methodology is to break plants into peer groups based on a primary cost driver (e.g. MW Capacity). This can create an issue at the margins of the peer groups in which plants at the upper end of a peer group range tend to look better when compared to plants at lower end simply due to economies of scale. As a result, a plant can appear to be a best performer in one peer group and then appear quite costly in another.

Developed by Oakridge National Labs for EUCG's Hydroelectric Productivity Committee (HPC), the Continuous Benchmark was the first formal attempt at adjusting for the economies of scale inherent in hydropower operations and maintenance costs, controlling for factors that lie outside of management control, and eliminating the benchmark discontinuities at the boundaries of the existing HPC peer groups. Statistical techniques were used to fit a continuous power law equation to HPC data that could be used to predict an expected cost for member facilities.

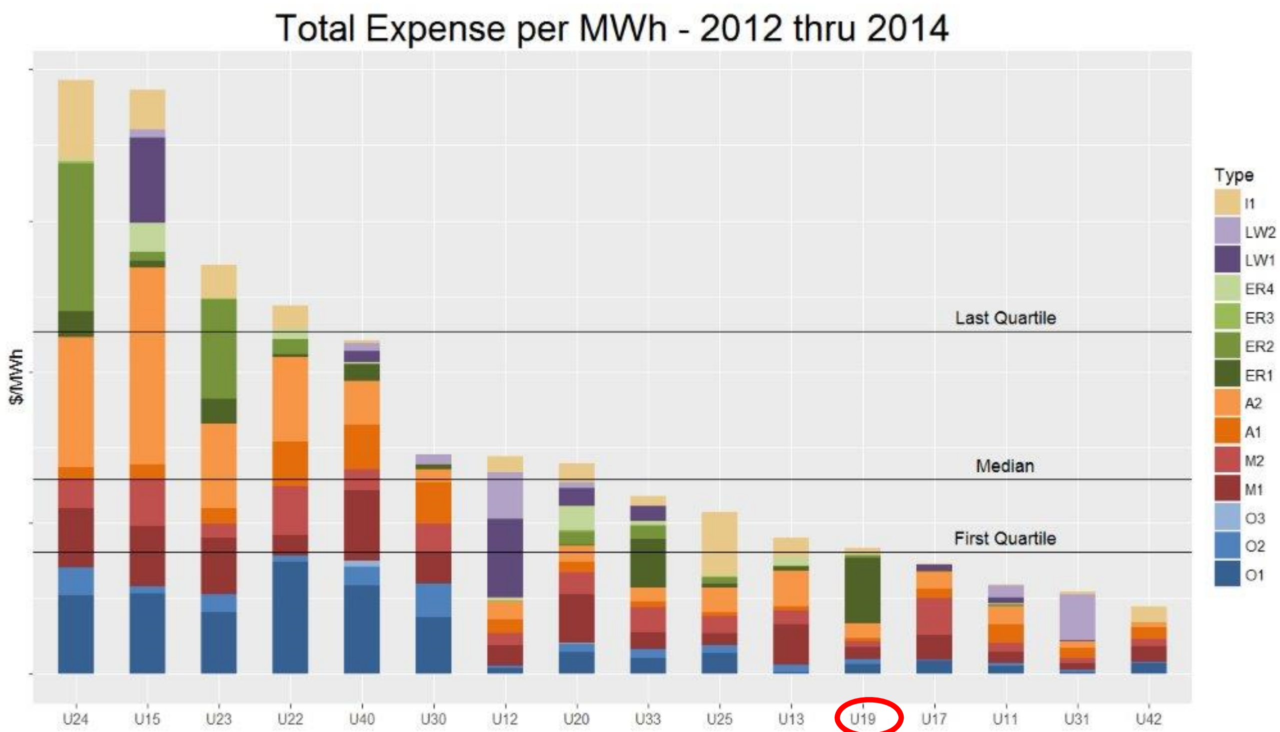
Measured in the Continuous Benchmark are all operations costs (powerhouse operations, generation planning, water management) and powerhouse routine maintenance costs. The result of the Continuous Benchmark is a predicted value for these costs controlling for the capacity and number of units at a facility, enabling comparison across all sizes of facilities.



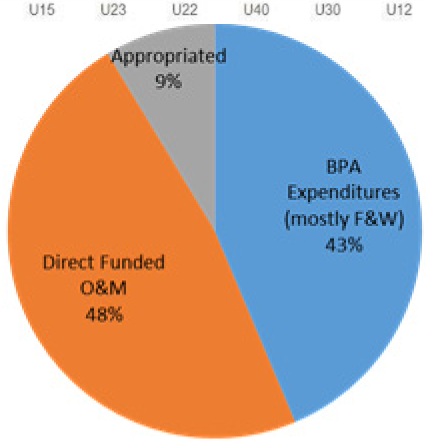
Note: Benchmark includes all operations costs and powerhouse maintenance only.

Plant	% of Benchmark
LMN	81%
HCR	84%
LGS	85%
COU	98%
IHR	100%
LWG	105%
CHJ	113%
TDA	115%
JDA	115%
DWR	116%
LOP/DEX	119%
LIB	121%
MCN	123%
DET/BCL	127%
GPR/FOS	132%
BON	132%
LOS	173%
ALB	238%

The majority of the Corps plants have actual costs above the continuous benchmark, suggesting that Operations and Powerhouse maintenance cost are relatively higher than expected for plants of their size and number of units. Ice Harbor, Lower Granite, Cougar and Hills Creek are just about at the industry benchmark while Little Goose and Lower Monumental have lower than expected costs.

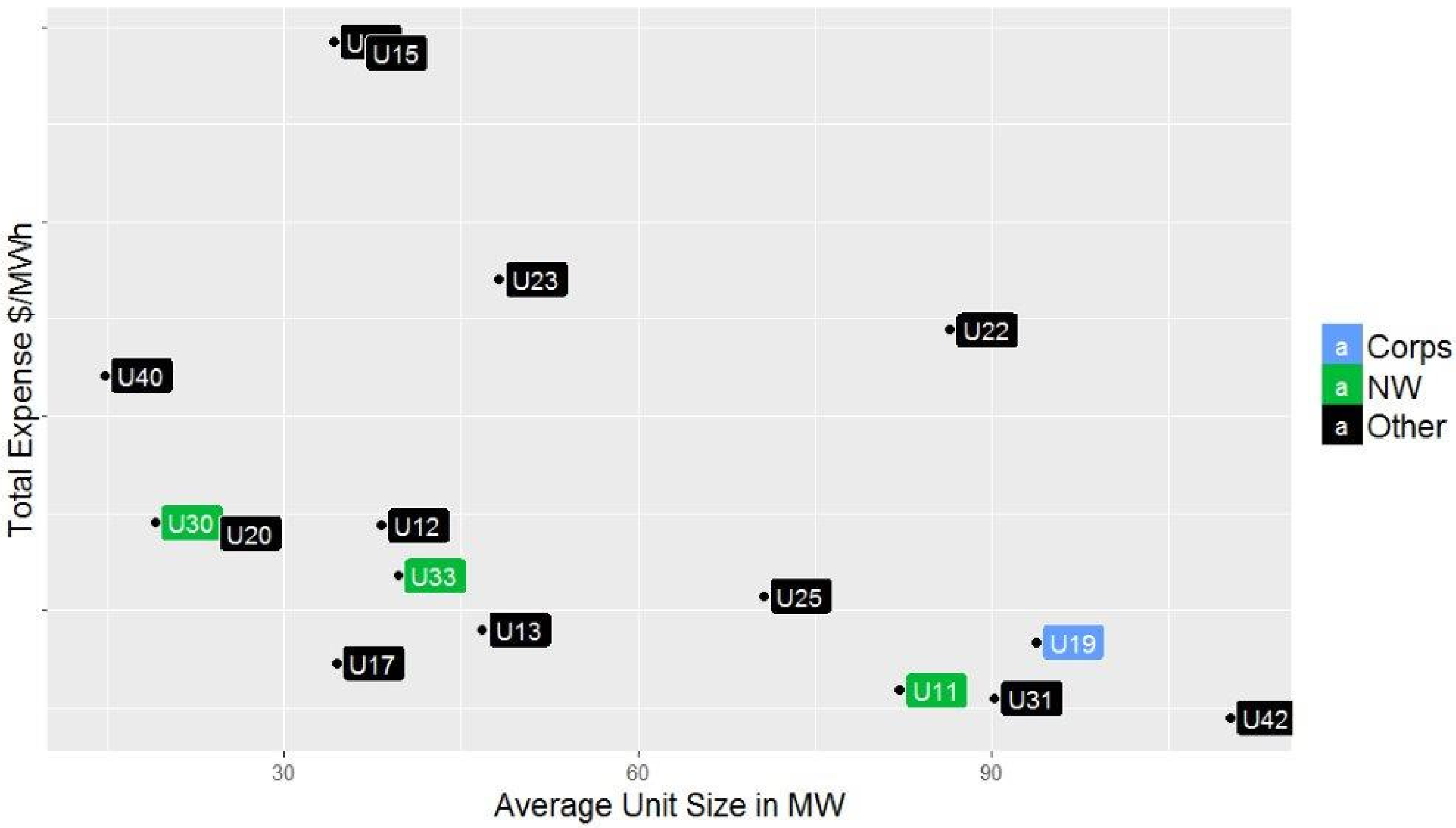


The continuous benchmark currently only incorporates a subset of two of the six cost categories measured in EUCG. When all expense cost categories are considered on a $/MWh basis, the FCRPS performs well compared to its peers. The FCRPS is represented by utility code U19 in the chart below.

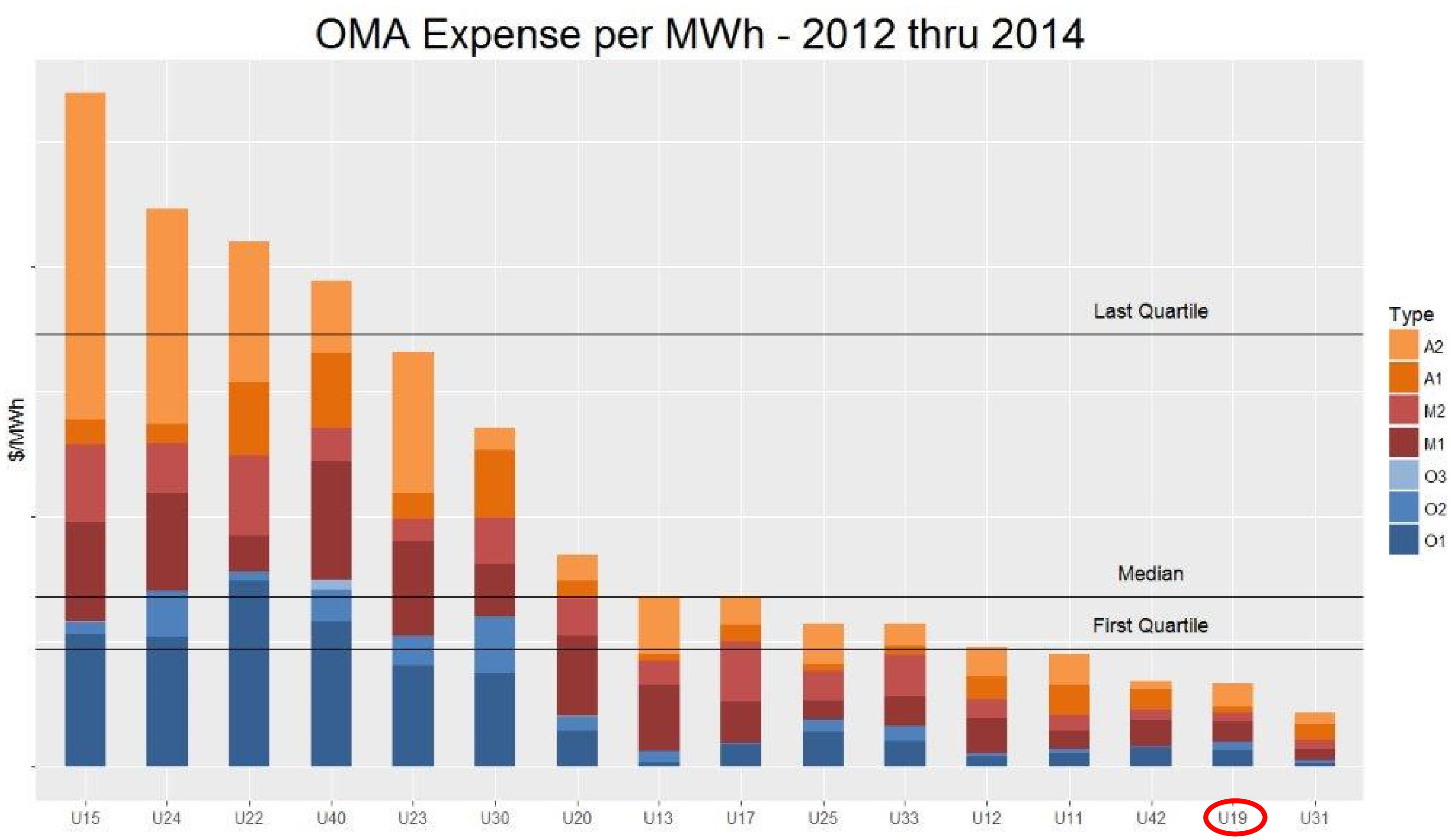


It should be noted that FCRPS expenses are inclusive of the total costs to produce hydropower, so they include more than just direct funds, BPA-incurred costs such as the F&W program, and appropriations from Congress. The graph to the left shows that direct funding is only about half of the benchmarked costs.

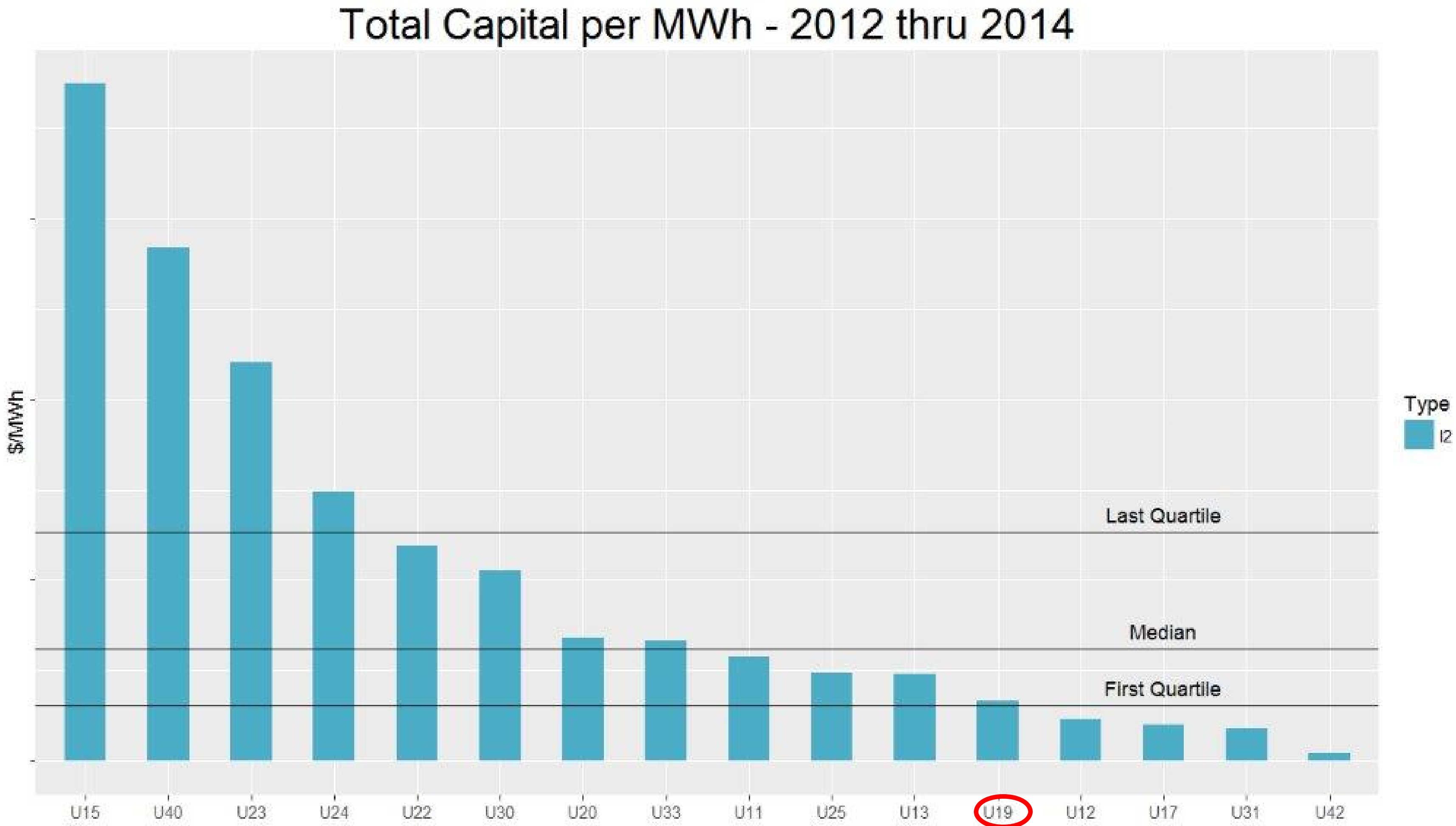
One of the most important drivers for hydro utility cost is fleet size, since large plants and units produce economies of scale. Although the FCRPS is one of the largest hydro fleets in EUCG, the below graph shows that even accounting for average unit size, the FCRPS is cost-competitive.



One reason the FCRPS does not have even lower cost is due to the level of funds directed towards activities other than direct operations and maintenance of the hydro projects. One commonly accepted analysis is to look at OMA-only costs, which focus on the essential functions of operations, maintenance and administration while ignoring environmental, regulatory, and investment costs. The FCRPS happens to have the second-highest percentage of costs devoted to non-OMA activities in EUCG (primarily due to our expansive Fish and Wildlife program).

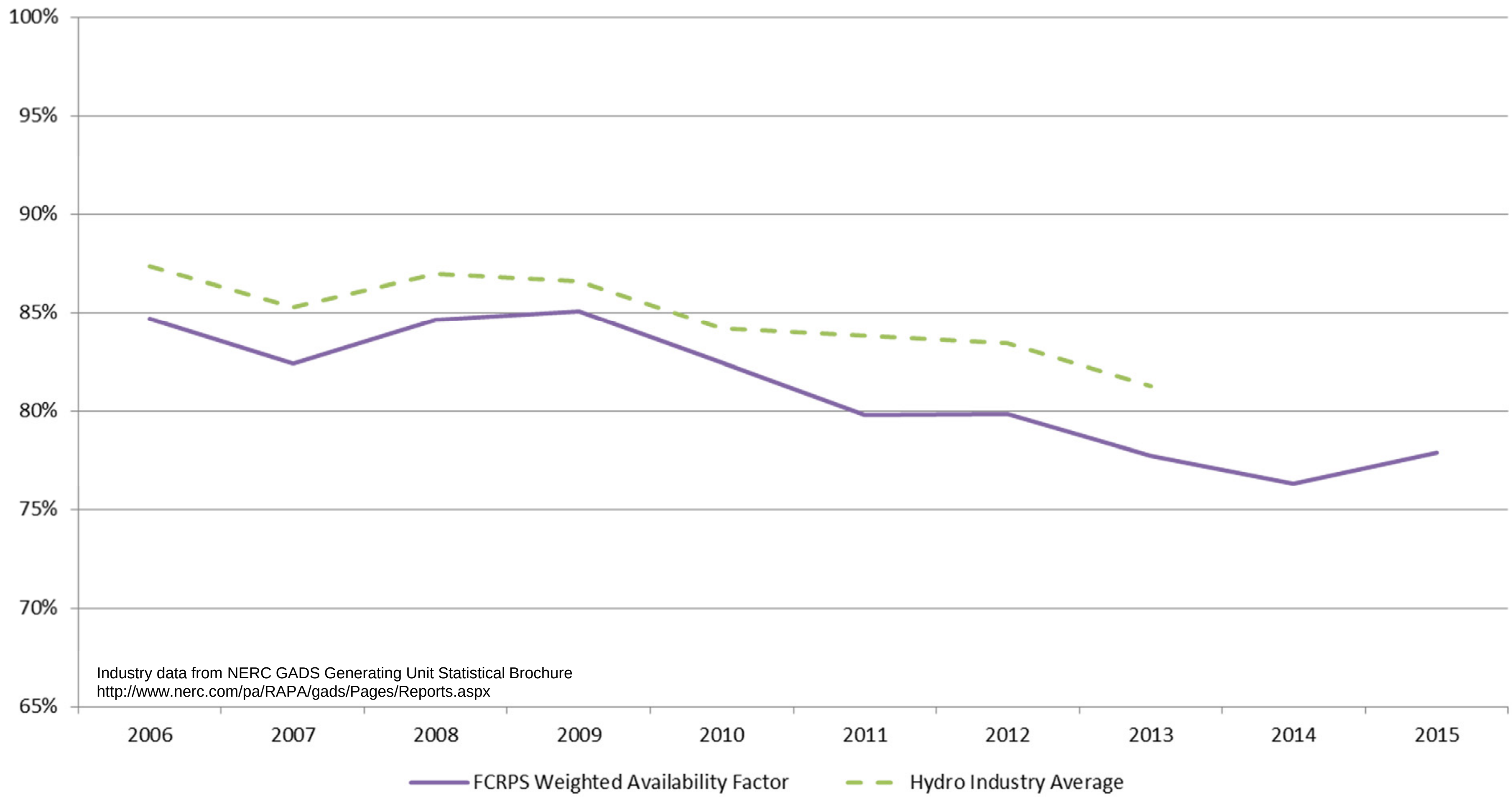


The levels of capital investment by MWh produced is shown below. Similar to total expense, the FCRPS spends capital at about the first quartile level. Additionally, three of the four utilities who spend less in capital per MWh spend more in maintenance than the FCRPS. It should be noted that a low $/MWh level of investment may be an indicator that the FCRPS is not investing at a sufficient level.



Current Performance, Power Reliability

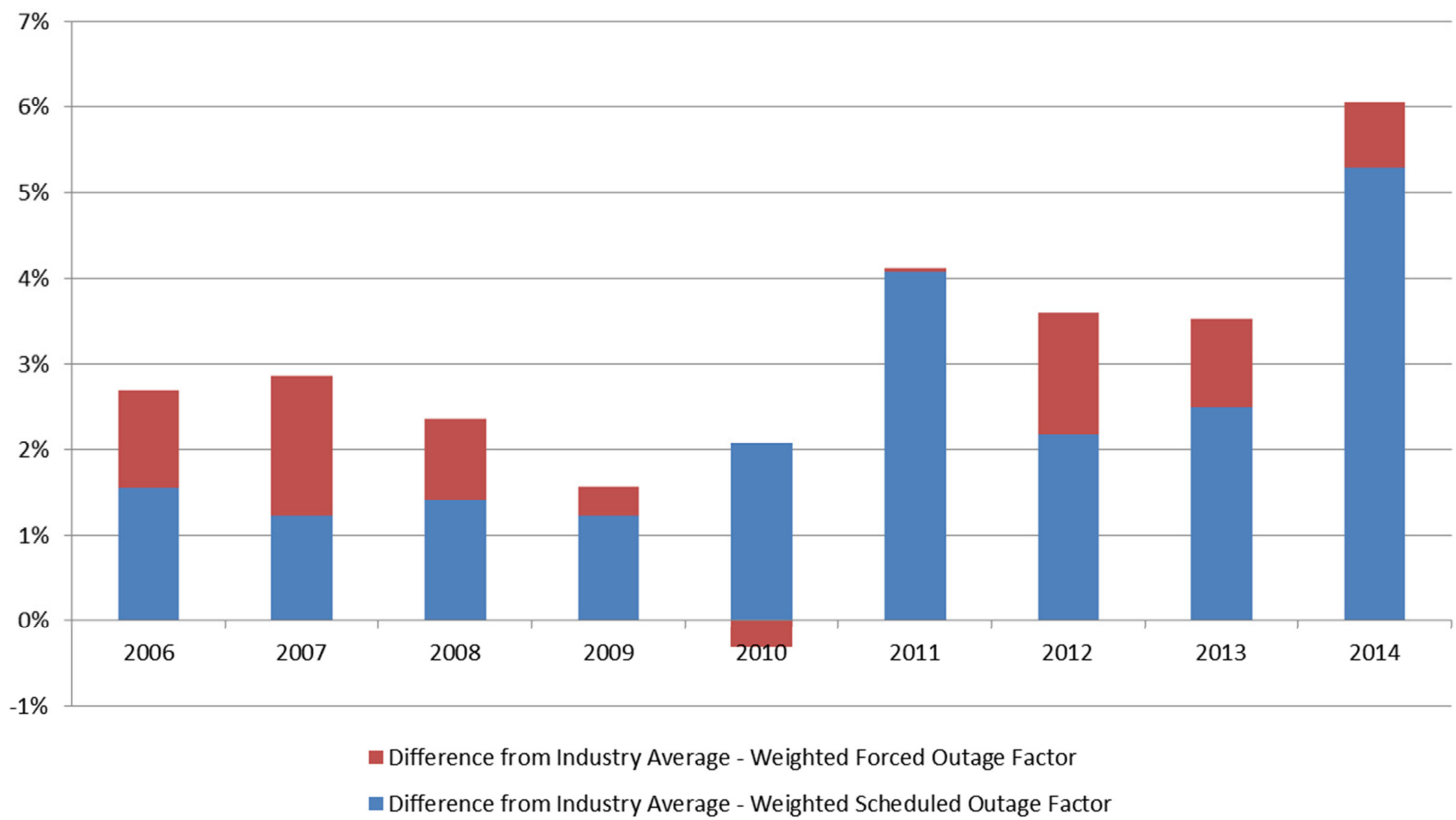
Availability



Availability in the FCRPS has followed the downward trend in availability observed throughout the hydroelectric industry over the last ten years. However FCRPS availability has been consistently lower than the industry average.

Current Performance, Power Reliability

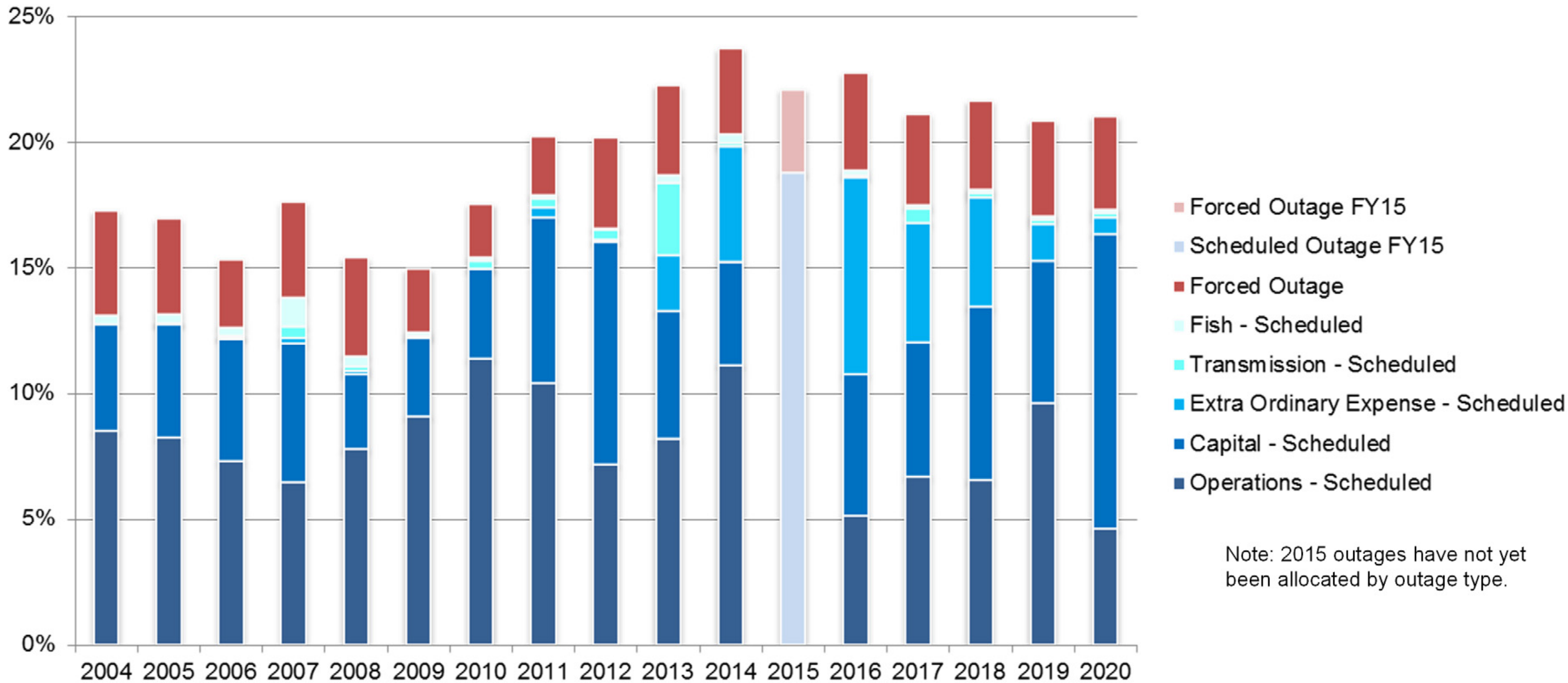
Difference from Industry Average



In most years, scheduled outages account for the majority of the deviation from industry average availability. Additional analyses are required to determine the impact of these outages and if actions can and should be taken to compress the schedules.

Current Performance, Power Reliability

Total Unavailability – Scheduled Outage Factor and Forced Outage Factor



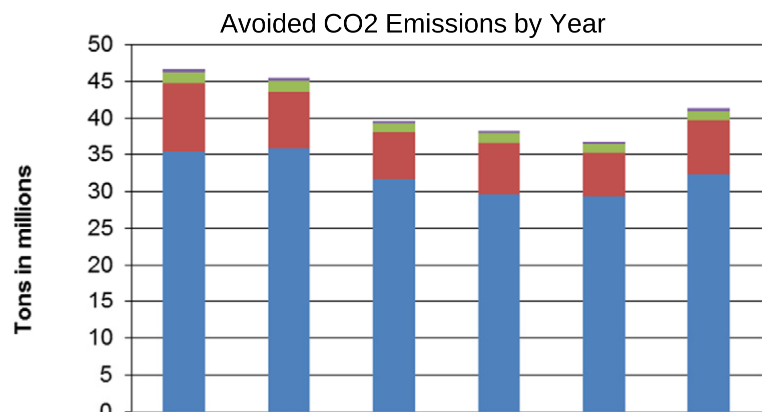
Declines in availability since 2009 can mostly be attributed to increasing scheduled outages associated with increases in capital and non-routine expense investments, specifically in the Third Powerplant at Grand Coulee. 2015 was the first year in which the outage factor has declined since 2012. This decline was projected in the FY15 5-Year availability analysis. The updated FY16 5-Year availability analysis is included above and projects further declines in scheduled outages.

In 2015, the FCRPS produced 69 million MWh of clean hydro generation, displacing energy that would have been generated by a fossil-fired resource alternative. Equivalent energy generated by a natural gas combustion turbine with a 8,039 BTU/kWh heat rate would have produced 36 million tons of CO2.

FCRPS hydro delivers positive climate change benefits by reducing the amount of emissions for electricity that would be generated by other sources were the hydro system not available.

The U.S. economy produces six billion tons of CO2 emissions each year, one third of which is produced by the electric power sector. The majority of electricity derived CO2 is produced by coal-fired power plants, with considerably less produced by natural gas and petroleum generation.

In an average water year, the FCRPS hydro system reduces the CO2 footprint of a natural gas-fired alternative by 39 million tons – about 0.7 percent of total U.S. emissions. Displacement of a coal-fired resource alternative would have an impact twice that of natural gas.



	2011	2012	2013	2014	2015	5-yr Avg
Local Support	0	0	0	0	0	0
Area Support	1	1	1	1	1	1
Headwater/Lower Snake	9	8	6	7	6	7
Main Stem Columbia	35	36	32	30	29	32

Following the trend in the utility industry, the FCRPS recently adopted DART (Days Away, Restricted or Transferred) as its main safety metric. Historically, the FCRPS has been above DART industry average, but there has been marked improvement since 2012. Lost Time Accidents have increased over the same period, suggesting that the improvements in DART have come primarily from reduced restricted and transferred duty incidents.

Days Away Restricted or Transferred per 200,000 person-hours

	2011	2012	2013	2014	2015
FCRPS	2.63	3.31	2.74	2.64	2.30
Industry Average	1.02	1.47	0.38	0.85	

*Industry Data from Edison Electric Institute for Hydroelectric Utilities

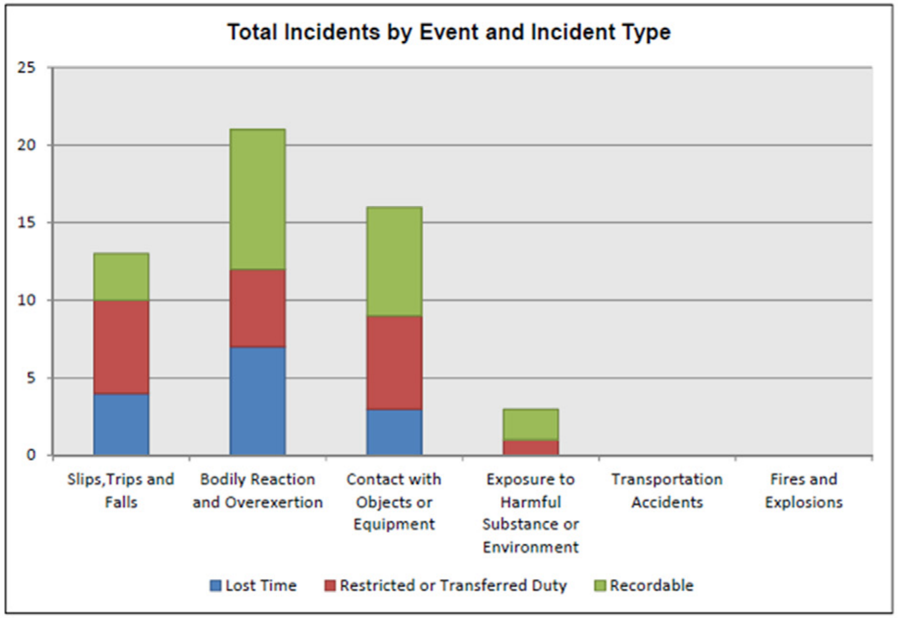
Lost Time Accidents per 200,000 person-hours

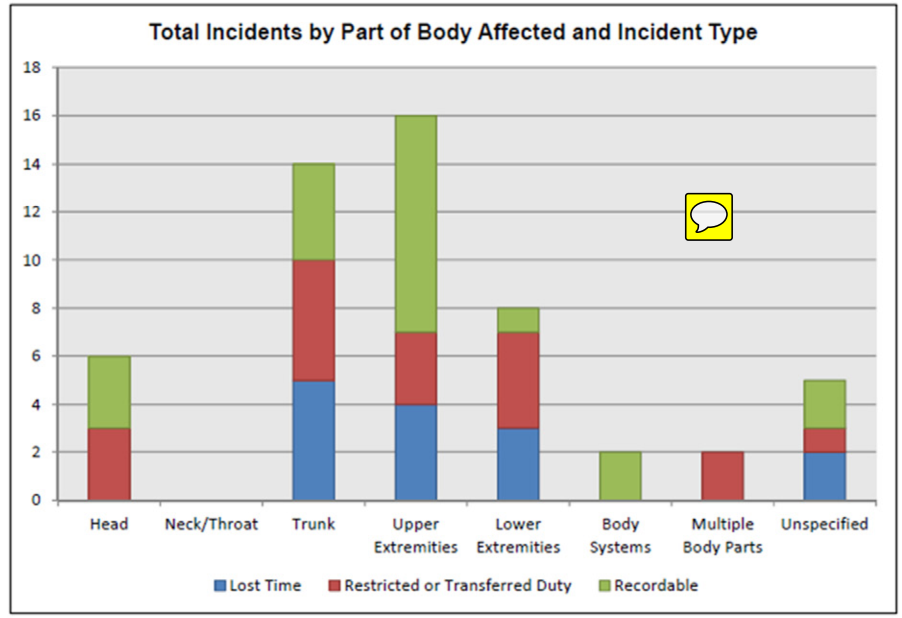
	2011	2012	2013	2014	2015
FCRPS	1.09	1.38	0.90	1.32	1.48
Industry Average	0.55	0.84	0.19	0.40	

*Industry Data from Edison Electric Institute for Hydroelectric Utilities

This strategy identifies a number of investments to improve safety and reduce safety risk across the FCRPS. Through 2030, there is roughly $200 million of investment need identified (in 2016 dollars) based on current and projected equipment condition and safety risk. These investments are primarily in the replacement or addition of fire protection systems (plant, control room and transformer) as well as water control and emergency closure assets (gates, bulkheads and stop logs). Additionally, arc flash safety improvements are being made across the system, coinciding with circuit breaker, station service and substation equipment replacements.

FY15 Safety Summary





The majority of lost time and restricted duty incidents are a result of bodily reaction or overexertion of the trunk or upper extremities. Generally, these are pulled muscles in the back, shoulders and arms. The next most frequent incident types are slips, trips and falls followed by injuries resulting from contact with objects or equipment.

A newly formed Three Agency Safety team will investigate how to improve safety across the FCRPS in the coming years. In the near term, pilot programs such as daily stretching classes have been implemented at some plants to reduce the frequency of muscle strain. In addition, the Bureau of Reclamation recently began sending regular emails regarding safety incidents to raise awareness throughout the region.

FEDERAL COLUMBIA RIVER
FCRPS
POWER SYSTEM

CURRENT AGE, CONDITION AND RISK

Age of Equipment

Background: Near term investment needs are driven primarily by component condition and risk. However, understanding component age helps to establish if equipment is nearing the end of its useful life and may soon present a risk to asset performance.

Furthermore, when age is profiled for the entire equipment portfolio it can become a tool to identify if near-term investment strategies could result in future investment needs that create unacceptable financial pressures or resource constraints.

The FCRPS has created age profiles of its facilities using “percent of design life” as a primary measure. For example, a 30 year old component with a design life of 40 years is represented as being at 75 percent of design life. This allows comparison across component types, recognizing that design life can vary considerably across component types or designs.

For presentation purposes, component ages have been grouped into four categories to create asset profiles. These categories are as follows:

- Less than 50 percent of design life;
- 50 to 100 percent of design life;
- 100 to 150 percent of design life, and
- Greater than 150 percent of design life.

Current Age by Strategic Class:

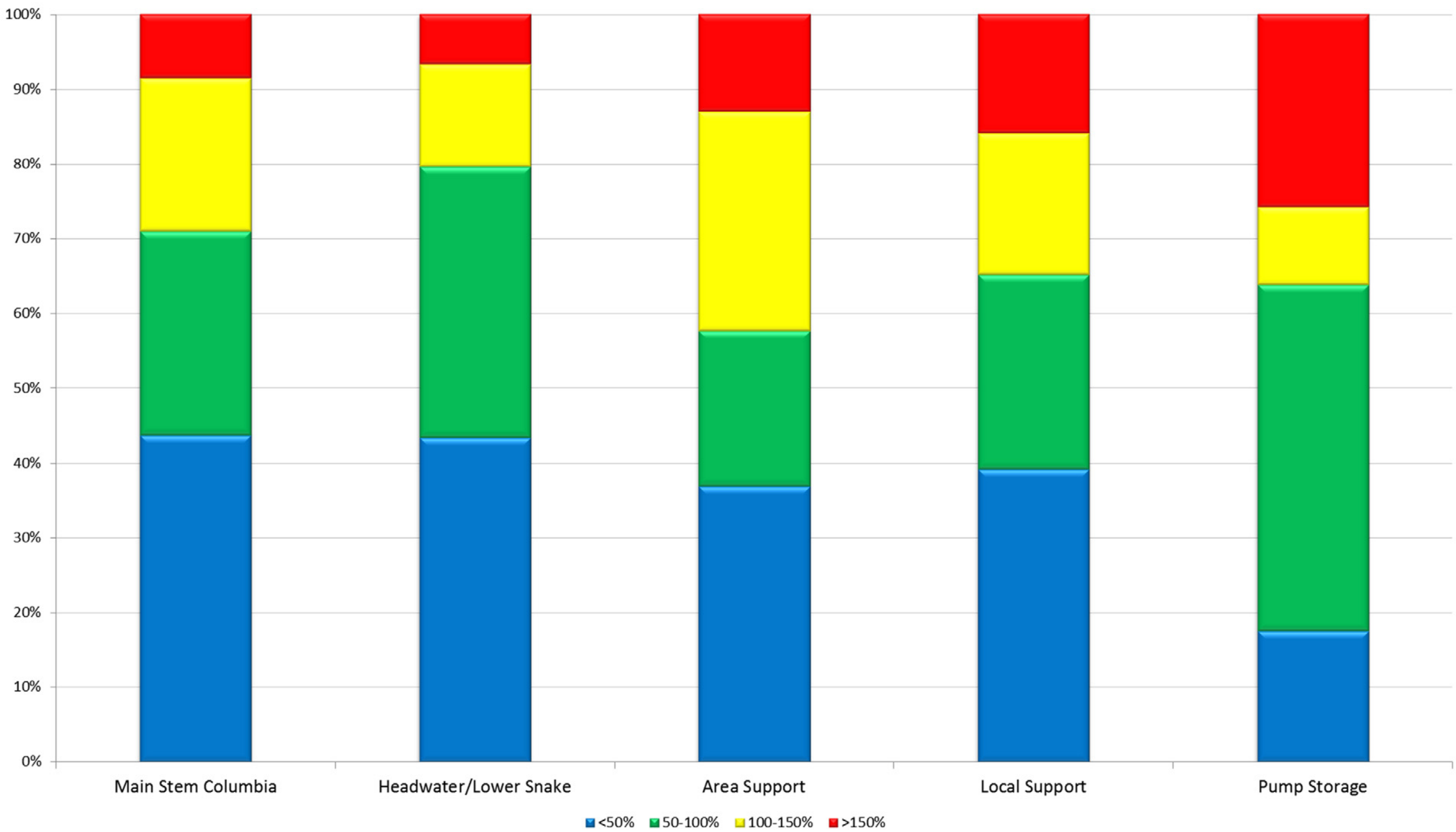
- About 30 percent of equipment has exceeded its design life in the Main Stem
- About 20 percent of equipment in the Headwater/Lower Snake class have exceeded design life.
- 42 percent of Area Support equipment is exceeding design life.
- 35 percent of equipment has exceeded design life in the Local Support class.

Current Age by Equipment Type:

- Nearly 60 percent of cranes have exceeded design life. The condition of cranes has declined fairly significantly in the past five years. The combination of condition and age make cranes a likely candidate for re-investment.
- Water control equipment (spillway electrical/mechanical and emergency closure) has the fewest percentage of components exceeding design life. However, the asset register needs to be expanded for this category.

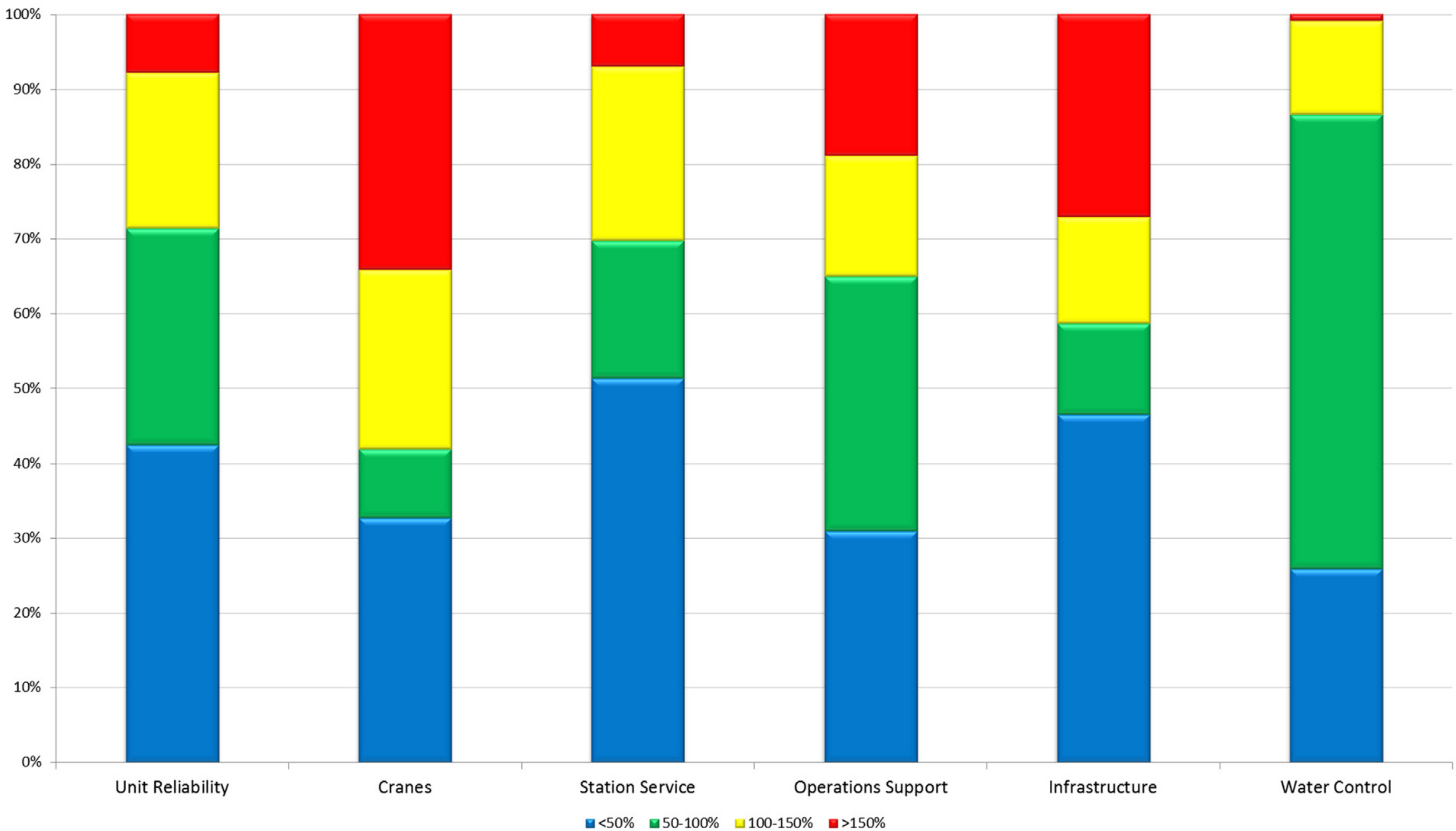
Current Age by Strategic Class: All Equipment

(Percent of Design Life)



Current Age by Equipment Type

(Percent of Design Life)



Condition Overview

The FCRPS manages 196 main generating units in 31 hydro plants, plus 16 additional station service, fish attraction, and pump turbine units. It considers over 5,500 equipment components in maintenance and investment planning.

Component condition is a key driver of maintenance and investment needs.

- Routine maintenance activities identify and address deficiencies prior to their posing threats to equipment reliability.
- Even with effective maintenance programs, condition will eventually deteriorate to the point where inadequate reliability will warrant reinvestment.
- Due to the nature and size of hydroelectric equipment, there are few redundant or spare components in hydroelectric generating facilities and, as such, it is important that the condition of major components be understood and managed.

Condition scores are determined using the hydroAMP condition assessment framework, a methodology used throughout the world for hydro asset condition assessment. Refer to Section 4 for a more detailed description of the hydroAMP program and how it is used in the analysis driving this strategy.

Condition Ratings

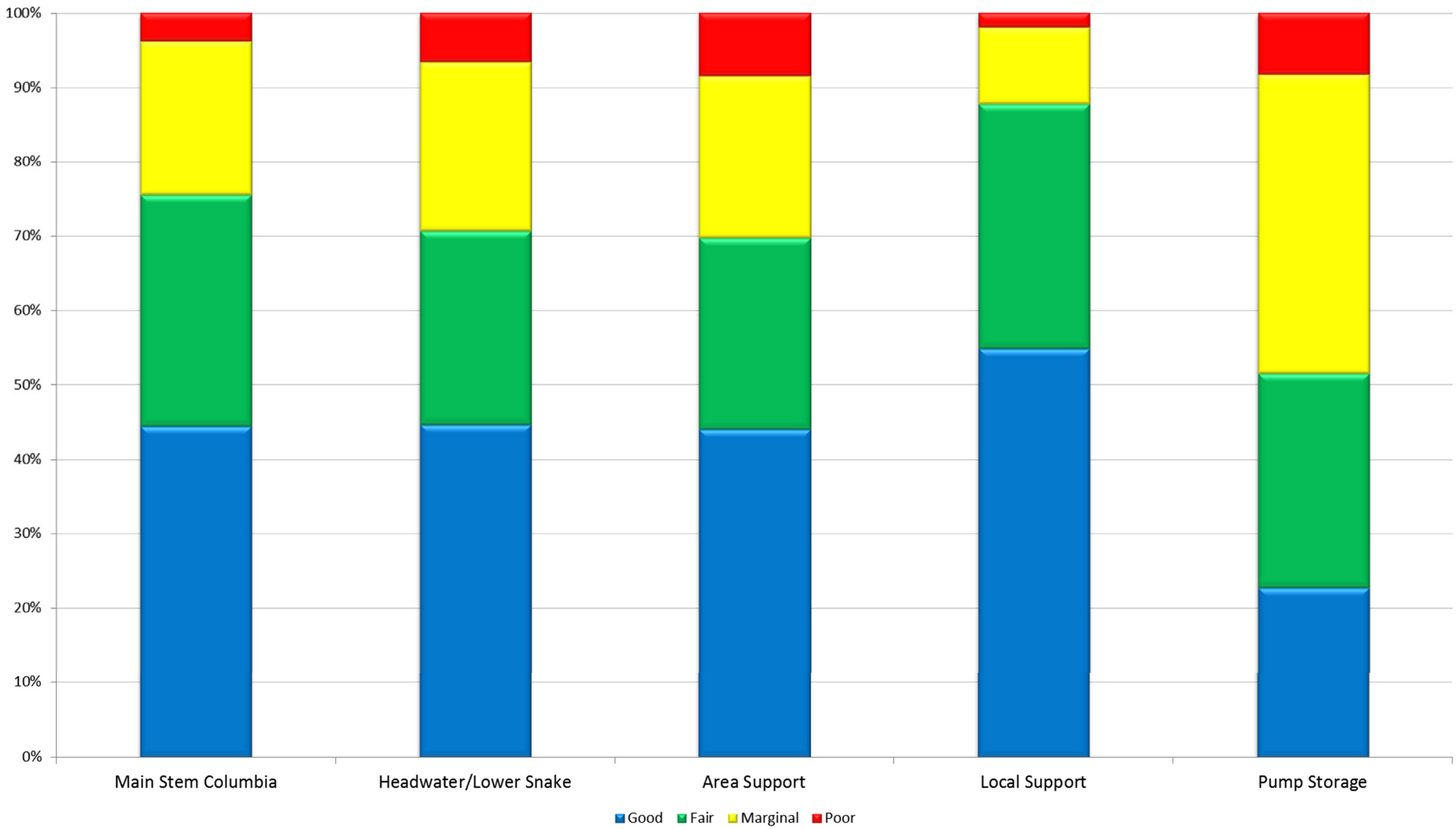
Condition ratings for each equipment type are based on a set of objective condition indicators related to operational performance, maintenance history, physical inspection, and age. Condition indicators are weighted and summed to derive a condition rating, ranging from 10 to 0. Numeric scores are further described qualitatively as follows:

- 8.0 – 10.0: Good
- 6.0 – 7.9: Fair
- 3.0 – 5.9: Marginal
- 0.0 – 2.9: Poor

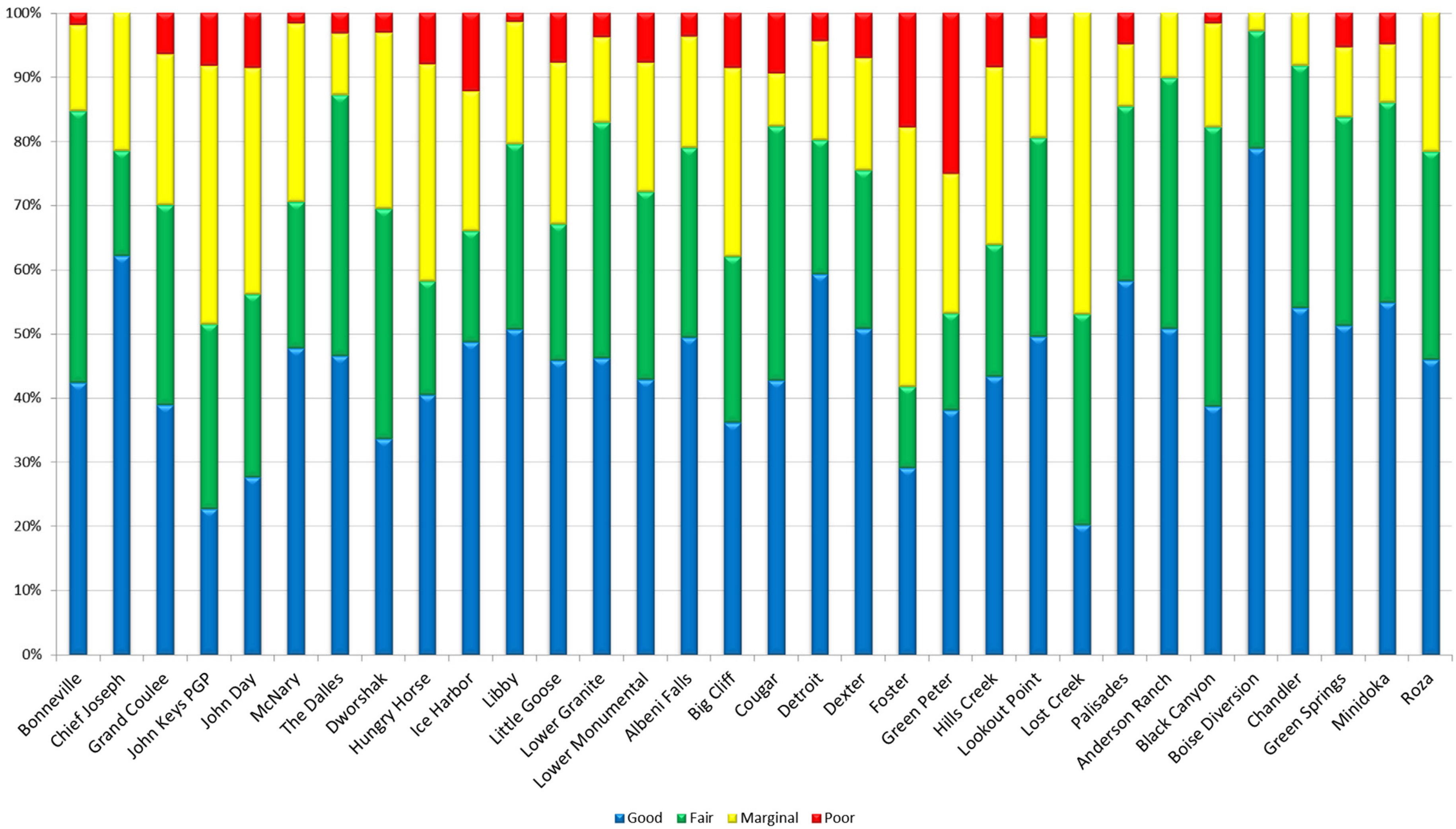
Condition by Strategic Class: About 25 percent of Main Stem Columbia assets are in Marginal or Poor condition. Headwater/Lower Snake and Area Support plants have somewhat lower ratings and Local Support plants as a group have higher condition ratings. Pump storage (John Keys III Pump Generating Plant) has the lowest condition rating of all strategic classes. Overall, 26 percent of FCRPS assets are in marginal or poor condition, 30 percent are in fair condition and 44 percent are in good condition.

Condition by Plant: Average condition rating by plant varies, with three critical plants – Grand Coulee, McNary and John Day – having below average ratings.

Current Condition by Strategic Class: All Equipment



Current Condition by Plant: All Equipment



Condition by Equipment Category:

- **Unit Reliability**: Generator Windings have the lowest overall condition with nearly 65 percent in Marginal or Poor condition. 30 to 35 percent of Turbine Runners and Components are in marginal or poor condition. Additionally, although the condition of governor electrical components have been improved across the system through digital Governor conversions, some of the remaining mechanical components are showing signs of age.

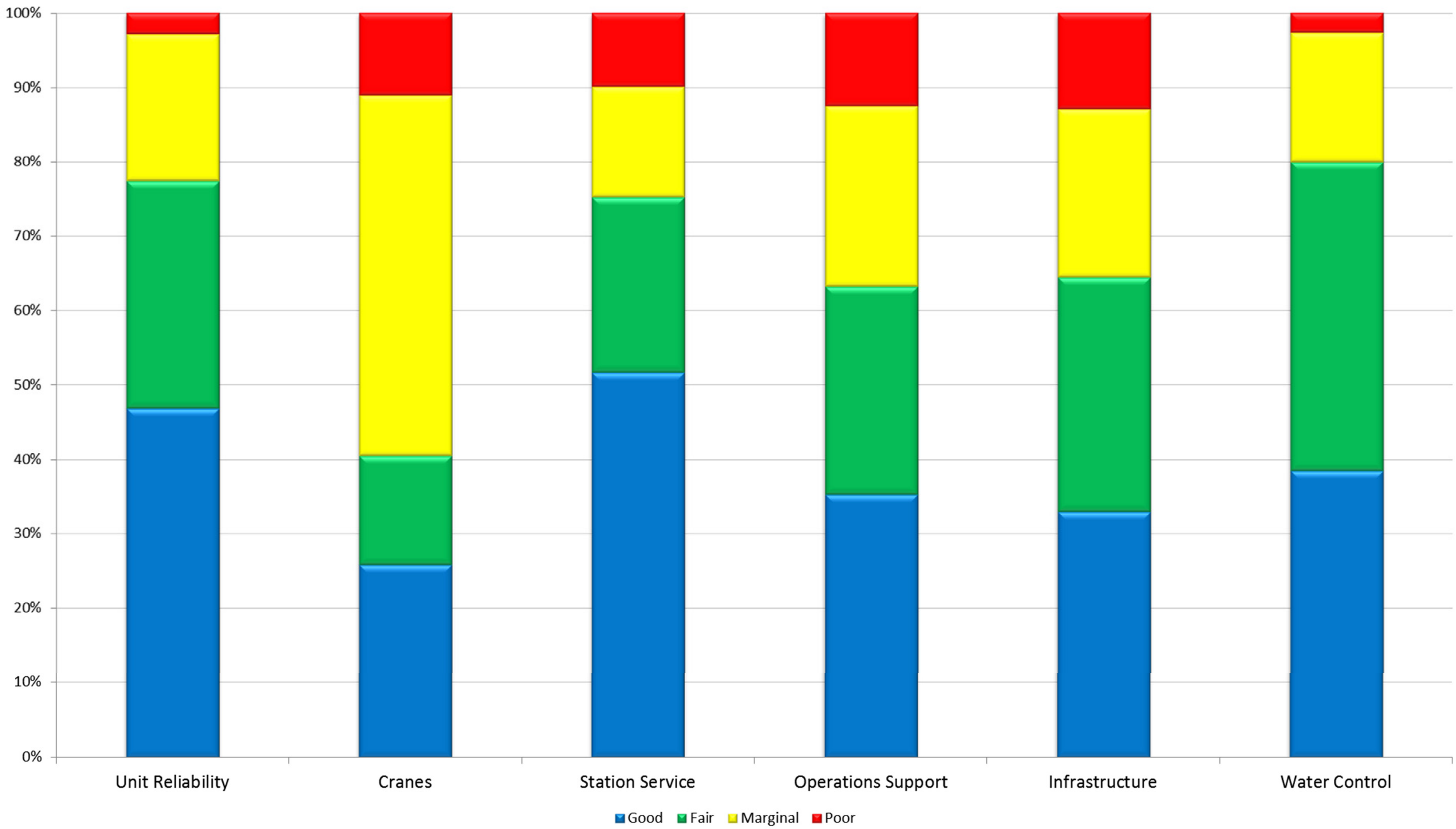
- **Cranes:** The lowest overall condition among all equipment types. Because cranes are needed to lift heavy equipment (including generation affecting equipment) and present considerable safety risk, satisfactory condition is a priority.

- **Station Service:** A reliable source of Station Service is critical to power plant operation. Although much of the Station Service category is in acceptable condition, Substation and Motor Control Center Equipment as well as DC System Boards and Breakers are showing degraded condition with 36 percent and 42 percent in poor or marginal condition respectively. Upgrades on these systems have already begun in the Willamette Valley and Lower Columbia.

- **Operations Support:** Condition Assessments are indicating that a majority of Plant Controls, Environmental Systems, Fire Protection and Detection and Security and Communication equipment are in marginal or poor condition. The modeling in this strategy tends to defer investment in these assets in favor of revenue generating equipment. Further investigation into the source of the declining condition is necessary at each facility to determine if replacement is warranted sooner than the analytics suggest.

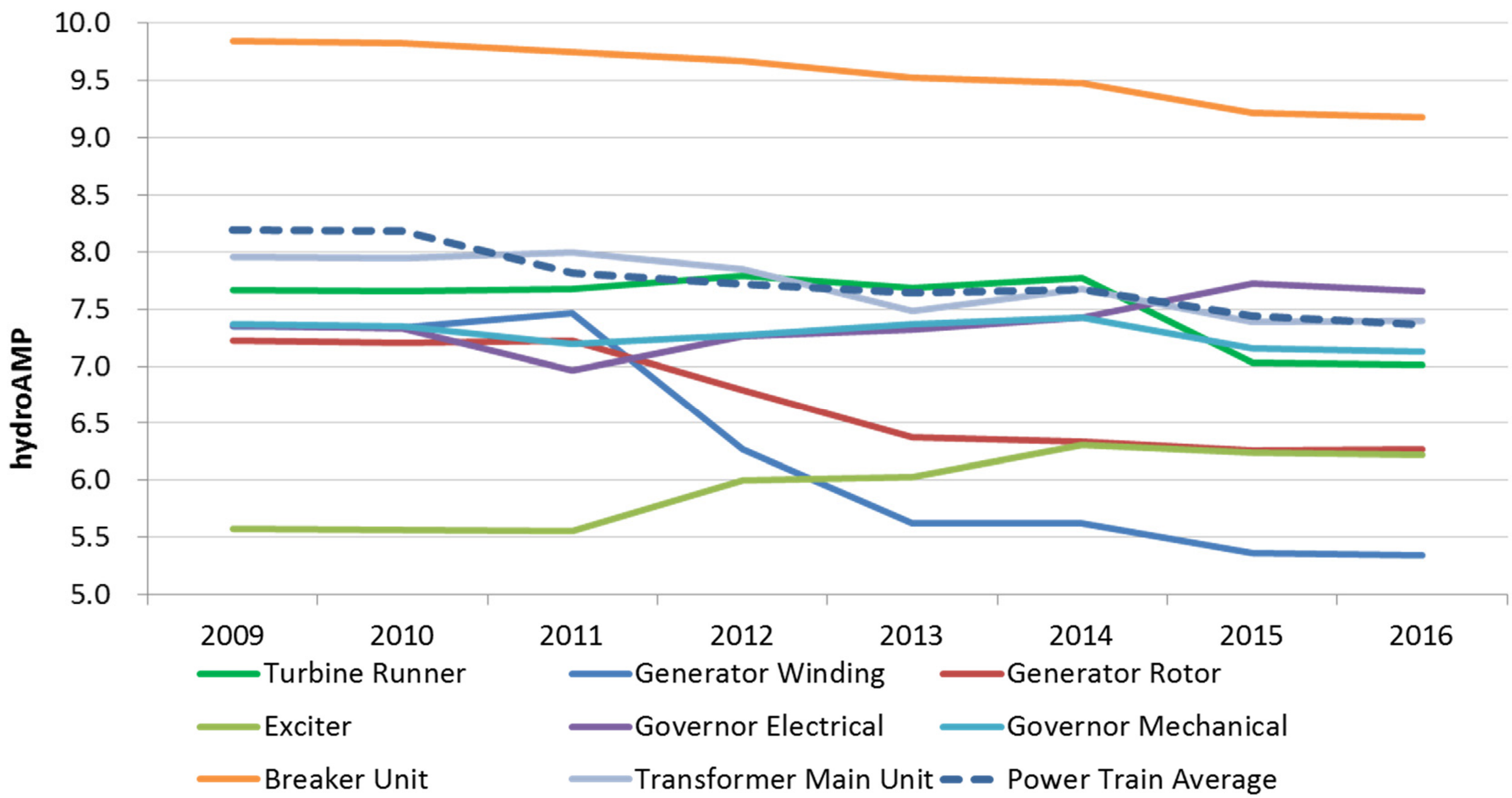
- **Infrastructure and Water Control:** HVAC systems are nearing the end of their service lives at a majority of the plants with deteriorating condition already resulting in replacements or plans for replacement.

Current Condition by Equipment Category



Trend of Condition Rating (2009-2016)

The megawatt weighted average condition for the system has declined from 7.7 to 7.4 over the past five years. The components in the best overall condition are unit breakers which have recently undergone a system-wide replacement program. The condition of generator windings declined significantly since 2011, in part due to a change in the condition indicator weighting algorithm which placed more emphasis on age, but also due to other factors at several plants, including Grand Coulee and more recently, John Day. Turbines and Main Unit Transformers have also experienced declining average condition in recent years.



FCRPS hydro asset management related risks are managed collaboratively by BPA's Generating Assets organization, the Bureau of Reclamation and the US Army Corps of Engineers. Asset management is the collective and collaborative efforts of these organizations.

Key requirements related to BPA's long-term outcomes are that the FCRPS:

- Meets equipment availability requirements (machine availability);
- Meets generation reliability standards, including compliance with WECC/NERC standards;
- Meets environmental requirements, particularly as related to management of water resources and equipment for fisheries purposes; and,
- Meets safety and security requirements.

Risk areas that could affect the long-term outcomes include the following:

- Failure of power train components;
- Failure of other generating station components not directly tied to the power system;
- Failure of Transmission assets;
- Effectiveness of security systems;
- Dynamic energy market conditions related to increasing renewable generation in California;
- Acts of nature; and
- Legal, regulatory and policy decisions that affect hydro operations or investment needs.

Failure of Hydro Plant Equipment

Loss of hydro plant equipment can lead to a number of negative consequences, including:

- Safety issues, should the catastrophic failure of a component cause injury or death;
- Economic losses as a result of the need to replace components;
- Economic losses as a result of the need to purchase replacement power to meet contractual obligations, or lost opportunities to sell power to the market;
- Environmental impacts such as the off-site release of oil;
- Regulatory violations through an inability to meet preferred unit operation, temperature controls, or Total Dissolved Gas (TDG) limits;
- Operational and Transmission support impacts such as unplanned spill or inability to provide reserves, voltage support, or capacity at peak periods, and
- Other stakeholder impacts such as lost pumping ability for Reclamation's irrigation customers.

The risk of equipment failure is assessed using two tools:

- Risk maps for safety, environmental and financial risk, and
- By quantifying lost generation risk.

The hydro program correlates a condition rating with the likelihood of equipment failing to perform as expected. An equipment component with a low condition rating has a higher likelihood of failure than one with a higher rating. The correlation is shown below.

Likelihood	Condition Index	Description
Almost Certain	0 to 0.9	Poor
	1 to 1.9	
	2 to 2.9	
	3 to 3.9	Marginal
	4 to 4.9	
	5 to 5.9	
	6 to 6.9	Fair
	7 to 7.9	
	8 to 8.9	Good
Rare	9 to 10	

Current Financial Risk Map

The financial risk map is also segmented into high, medium, and low risk areas.

Financial consequences are a result of two factors in the event of a failure:

- The cost of replacement power for any lost generation, and
- Incremental direct costs for collateral damage, procurement, and scheduling/workforce inefficiencies.

There are currently 340 equipment items in the high risk area of the map, 14 more than in the 2016 Strategy:

- 192 Unit Reliability
- 18 Cranes
- 78 Station Service
- 27 Operations Support
- 17 Infrastructure
- 8 Water Control

Current Financial Risk Map

Likelihood	Insignificant < $ 10K	Minor $ 10K to $ 100K	Moderate $ 100K to $ 1 M	Major $ 1 M to $ 10 M	Extreme > $ 10 M
Almost Certain	5 Operations Support	10 Unit Reliability 6 Station Service 21 Operations Support 3 Water Control	25 Unit Reliability 2 Cranes 19 Station Service 24 Operations Support 14 Infrastructure 1 Water Control	17 Unit Reliability 20 Station Service 1 Operations Support 3 Infrastructure 2 Water Control	3 Unit Reliability
Likely	5 Station Service 12 Operations Support	7 Unit Reliability 2 Cranes 18 Station Service 9 Operations Support 2 Water Control	36 Unit Reliability 11 Cranes 12 Station Service 34 Operations Support 16 Infrastructure 16 Water Control	131 Unit Reliability 16 Cranes 37 Station Service 2 Operations Support 4 Water Control	16 Unit Reliability 2 Station Service 1 Water Control
Possible	9 Operations Support 1 Infrastructure	42 Unit Reliability 10 Station Service 20 Operations Support 3 Infrastructure 2 Water Control	64 Unit Reliability 52 Cranes 20 Station Service 25 Operations Support 14 Infrastructure 15 Water Control	313 Unit Reliability 42 Cranes 64 Station Service 3 Operations Support 2 Infrastructure 3 Water Control	90 Unit Reliability 4 Cranes
Unlikely	8 Operations Support 1 Infrastructure	21 Unit Reliability 2 Station Service 5 Operations Support 6 Infrastructure	56 Unit Reliability 7 Cranes 7 Station Service 5 Operations Support 10 Infrastructure 5 Water Control	193 Unit Reliability 2 Cranes 26 Station Service 1 Operations Support 6 Water Control	68 Unit Reliability 1 Water Control
Rare	9 Station Service 101 Operations Support 4 Infrastructure	330 Unit Reliability 2 Cranes 113 Station Service 70 Operations Support 17 Infrastructure 15 Water Control	881 Unit Reliability 44 Cranes 133 Station Service 49 Operations Support 58 Infrastructure 121 Water Control	1211 Unit Reliability 33 Cranes 126 Station Service 4 Operations Support 6 Infrastructure 23 Water Control	242 Unit Reliability 16 Station Service 4 Water Control

Consequence

Condition: 0 – 10

Risk Level	Low	Medium	High

Safety and Environmental Risk Maps

Risk is the product of likelihood and consequence. Two items with the same potential consequence will have different levels of risk if the likelihood of occurrence differs.

On the following maps, both safety and environmental risks are identified as being high, medium, or low.

- Safety consequences range from a low of “first aid required” to a high of “multiple fatalities”.
- Environmental consequences range from “no impact” to “detrimental or catastrophic off-site impact”.

Safety: High risk items have declined for Operations Support and Water Control Items since the 2016 strategy:

- 25 Water Control items (vs. 32 in the 2016 Strategy)
- 43 Operations Support (vs. 50)

However high risk items have increased for Unit Reliability and Station Service:

- 20 Unit Reliability (vs. 10)
- 1 Station Service (vs. 0)

Environmental: Similarly, high environmental risk items in Operations Support and Water Control declined since the 2016 strategy, while Unit Reliability and Station Service increased.

- 25 Water control (vs. 33)
- 50 Operations support (vs. 53)
- 18 Unit Reliability (vs. 6)
- 1 Station Service (vs. 0)

Current Safety Risk Map

Likelihood	0 → 10 (Condition)	No or minor injury, first aid	Treatment by medical professional	Lost time Accident - temporary disability	Lost Time Accident - permanent disability/fatality	Multiple fatalities
Almost Certain	0	19 Unit Reliability 39 Station Service 6 Operations Support 8 Infrastructure	18 Unit Reliability 2 Cranes 5 Station Service 11 Operations Support 9 Infrastructure	2 Unit Reliability 1 Station Service 21 Operations Support	13 Operations Support	16 Unit Reliability 6 Water Control
Likely		109 Unit Reliability 45 Station Service 6 Operations Support 13 Infrastructure 2 Water Control	71 Unit Reliability 13 Cranes 26 Station Service 14 Operations Support 3 Infrastructure 2 Water Control	8 Unit Reliability 16 Cranes 3 Station Service 28 Operations Support	9 Operations Support	2 Unit Reliability 19 Water Control
Possible		412 Unit Reliability 62 Station Service 3 Operations Support 15 Infrastructure	47 Unit Reliability 53 Cranes 24 Station Service 25 Operations Support 5 Infrastructure 4 Water Control	32 Unit Reliability 45 Cranes 8 Station Service 23 Operations Support	6 Operations Support	18 Unit Reliability 16 Water Control
Unlikely		291 Unit Reliability 26 Station Service 5 Operations Support 12 Infrastructure	22 Unit Reliability 7 Cranes 2 Station Service 5 Operations Support 5 Infrastructure	20 Unit Reliability 2 Cranes 7 Station Service 7 Operations Support	2 Operations Support	5 Unit Reliability 12 Water Control
Rare	10	1876 Unit Reliability 205 Station Service 74 Operations Support 47 Infrastructure 3 Water Control	363 Unit Reliability 39 Cranes 118 Station Service 77 Operations Support 38 Infrastructure 28 Water Control	191 Unit Reliability 40 Cranes 74 Station Service 50 Operations Support	23 Operations Support	234 Unit Reliability 132 Water Control

Consequence

Risk Level	Low	Medium	High

Current Environmental Risk Map

Likelihood		No impact	Impact to on-site environment (simple remediation)	Limited impact off-site (localized remediation required)	Detrimental impact on- or off-site (long-term remediation required)	Detrimental or catastrophic impact off-site (mitigation impossible)
	Almost Certain	19 Unit Reliability 2 Cranes 39 Station Service 6 Operations Support 17 Infrastructure	18 Unit Reliability 5 Station Service 3 Operations Support	18 Unit Reliability 1 Station Service 37 Operations Support	5 Operations Support	6 Water Control
	Likely	99 Unit Reliability 13 Cranes 45 Station Service 6 Operations Support 16 Infrastructure	81 Unit Reliability 26 Station Service 6 Operations Support	10 Unit Reliability 16 Cranes 3 Station Service 37 Operations Support 4 Water Control	8 Operations Support	19 Water Control
	Possible	339 Unit Reliability 53 Cranes 62 Station Service 3 Operations Support 20 Infrastructure	120 Unit Reliability 24 Station Service 4 Operations Support	50 Unit Reliability 45 Cranes 8 Station Service 40 Operations Support 4 Water Control	10 Operations Support	16 Water Control
	Unlikely	158 Unit Reliability 7 Cranes 26 Station Service 5 Operations Support 17 Infrastructure	155 Unit Reliability 2 Station Service 3 Operations Support	25 Unit Reliability 2 Cranes 7 Station Service 10 Operations Support	1 Operations Support	12 Water Control
	Rare	1684 Unit Reliability 39 Cranes 205 Station Service 74 Operations Support 85 Infrastructure	555 Unit Reliability 118 Station Service 10 Operations Support	425 Unit Reliability 40 Cranes 74 Station Service 116 Operations Support 31 Water Control	24 Operations Support	132 Water Control

Consequence

Condition: 0 (top) to 10 (bottom)

Risk Level	Low	Medium	High

Current Lost Generation Risk

Failure likelihood and consequence information is further evaluated to quantify the expected value of lost generation as Lost Generation Risk (LGR).

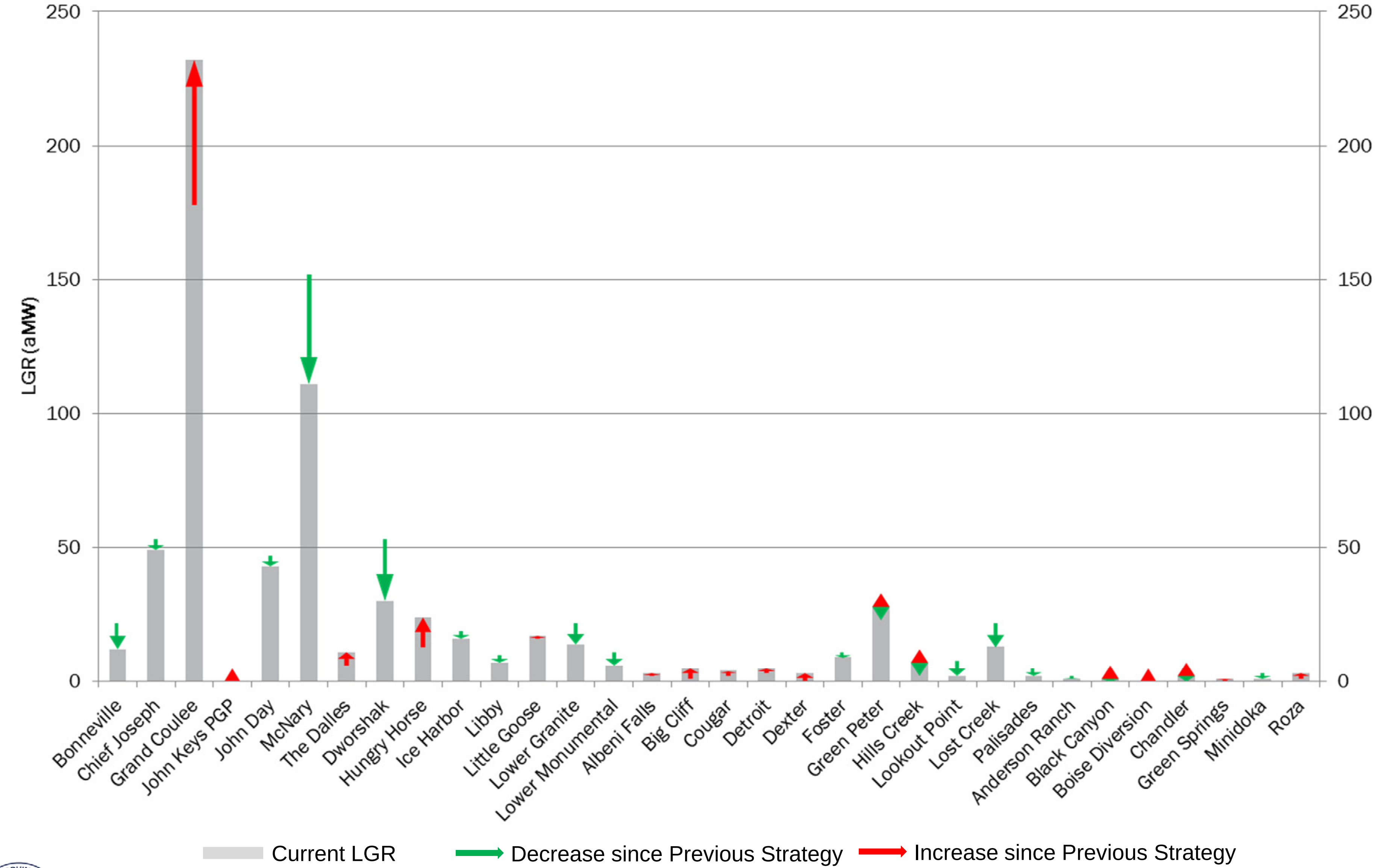
- Equipment condition correlates to a probability of failure for each component.
- These probabilities are multiplied by the lost generation consequence for each component to calculate the Lost Generation Risk, i.e., the replacement power cost risk associated with a run-to-failure strategy.

Total system LGR is an annual aggregation of the likelihood and consequence of failure for each piece of equipment in a given year. The 2016 LGR for the system is about 662 aMW, down from 702 aMW two years ago and very close to the 678 aMW projection for 2016 in the previous strategy.

- Reduction primarily driven by the completion of six generator rewinds at McNary since the last Asset Strategy as well as higher condition scores at Bonneville and Dworshak.
- The increase in risk at Grand Coulee is a result of as-found condition on Unit 24. Assets that were found with lower than expected condition are already planned for replacement or refurbishment as part of the Third Powerplant overhaul.

About 70 percent of current LGR is in the Main Stem Columbia class (458 aMW). Grand Coulee accounts for more than half of the LGR in the Main Stem with 249 aMW, attributable mostly to the condition of generator windings, transformers, exciters, and in the Third Powerplant, turbines. McNary is the second largest contributor with 113 aMW of LGR, driven primarily by turbine runners and components, as well as the three remaining generator windings that have yet to be replaced. The remainder of LGR in the Main Stem is primarily due to the condition of turbines, windings, exciters and governors at Chief Joseph (49 aMW) as well as turbines and windings at John Day (43 aMW). Most other plants have LGR of less than 30 aMW.

Change in Lost Generation Risk by Plant since the Previous Strategy



4. HYDRO INVESTMENT STRATEGY, METHODOLOGY AND ASSUMPTIONS

Investments to maintain equipment reliability are less about “if” than “when” to make repairs or replacements.

This 2018 Hydro Asset Strategy takes a risk-based approach to identifying the optimum time for making new investments, consistent with the approach used for the 2012 and 2014 strategies. A detailed explanation of the prioritization logic is included in Appendix B.

The strategy is consistent with BPA’s asset management policy, which states:

- *BPA will invest in, maintain, and operate assets to:*
    - *Meet reliability standards, availability requirements, regional adequacy guidelines, efficiency needs, environmental requirements, safety and security standards, and other requirements.*
    - *Minimize the life cycle costs of assets when practical.*

Optimal replacement dates for over 5,500 assets are calculated by:

- Assessing current condition and forecasting how it changes over time
- Relating asset condition to an effective age and probability of failure for each asset type
- Multiplying the consequence of failure by the probability of failure for each asset type to determine the risk posed by the asset in a given year
- Minimizing the sum of the present value risk costs and replacement cost

Using the hydroAMP condition assessment framework, the FCRPS assesses the condition of power train and critical ancillary components on an annual basis with the remaining components, known as balance of plant equipment, assessed biennially. The hydroAMP guide contains specific instructions for the objective condition assessment of the power train and critically ancillary equipment. A more generic guide was created for the balance of plant assets to more subjectively assess the condition of more than eighty additional components.

Condition Assessment guides have been written collaboratively by subject matter expert teams with representation from Bonneville Power Administration, Army Corps of Engineers, Bureau of Reclamation, Chelan PUD, Seattle City Light and Hydro Quebec. Guides are periodically reviewed and revisited by the hydroAMP Steering Committee of which the above utilities are members.

Development of the hydroAMP framework is supported by the 60+ member utilities of CEATI's Hydraulic Plant Life Interest Group (HPLIG). With fifteen utilities actively contributing condition assessment data to the hydroAMP web application and many more using the assessment guides offline, hydroAMP has become the de facto standard for hydro asset condition assessment.

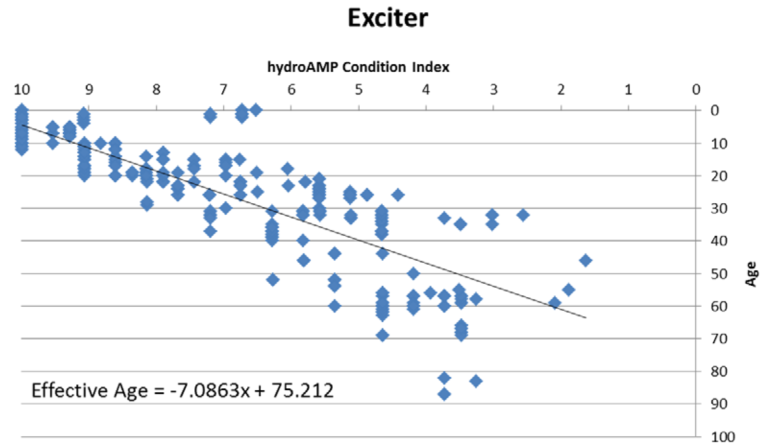
There are currently over 5,500 FCRPS assets in hydroAMP. All powertrain assets (Turbines, Generator Rotors and Stators, Governors, Excitation Systems, Transformers and Circuit Breakers) are inventoried for each plant and represent about thirty percent of the assets in the hydroAMP.

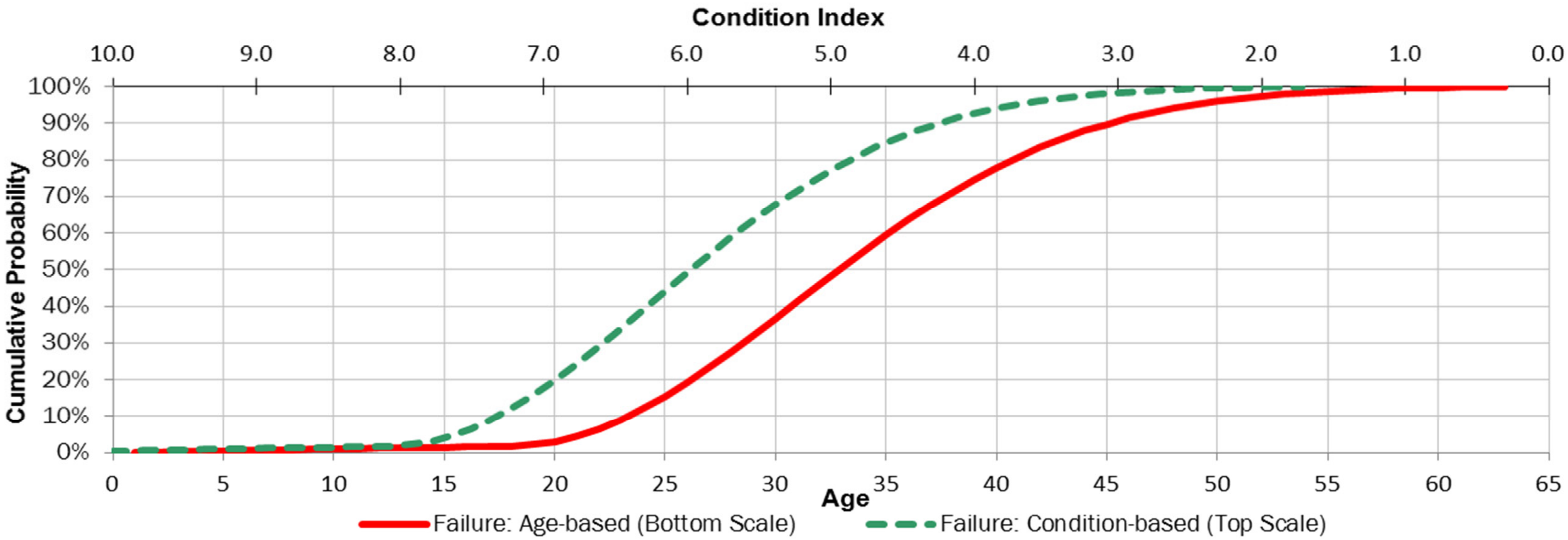
Remaining components are categorized as critical ancillary and balance of plant equipment, some of which have direct impacts on generation. The inventory of assets in these categories is less consistent across the plants in the FCRPS. Improvements in the consistency of asset identification throughout the FCRPS as well as improvements in how the condition assessments are collected and quality-controlled are being discussed as part of the Asset Investment Excellence Initiative (AIEI). More information on the AIEI can be found in Attachments 1 and 2 of this strategy.

Equipment Condition and its Relationship to Risk

A regression analysis was performed on the hydroAMP database to establish a correlation between a condition index and equipment "effective age". The results were then used to map the hydroAMP condition index and effective age to a survivor curve for that equipment. Survivor curves are derived from industry data and show the relationship between equipment age and the percentage of the equipment population that has failed or been retired. This regression also serves as the basis for hydroAMP condition degradation projections, with a mix of both linear and nonlinear curves fit for each respective equipment type. Condition degradation curves are used to forecast future equipment condition as equipment ages and condition declines. Mapping the hydroAMP results to the survivor curve yields a failure probability for equipment with a certain condition index and effective age.

The basis for the existing powertrain equipment failure curves comes from a 2003 CEATI Hydro Plant Life Interest Group project that was sponsored by 11 utilities throughout North America, Europe and Australia. Failure and retirement data was provided by each of the sponsoring utilities. Weibull parameters were fit to the unit survival data using a standard least squares method, weighted by the number of exposed units at a given age.





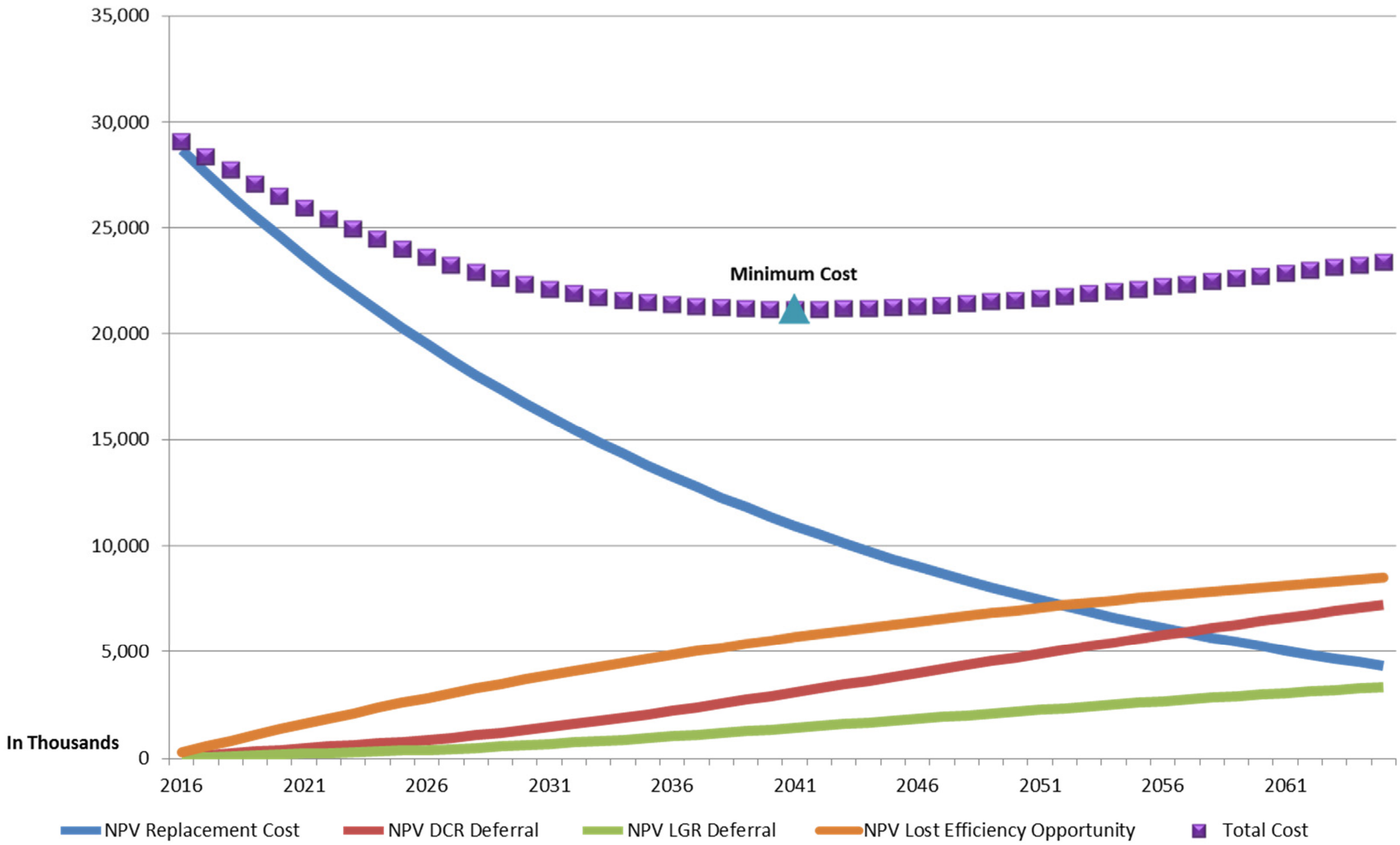
Economics of Risk Intervention at Different Points in Time

With an understanding of condition, how it changes without intervention and how it relates to a probability of failure, risk can be forecast over time. Without corrective action (intervention), equipment condition degrades over time. As equipment condition degrades, the likelihood (and risk) of equipment failing to perform as expected increases.

Four factors influencing the economics of risk intervention are outlined in the diagram on the next page. All curves show the present value of costs over time.

- **Replacement Cost** – Typically, the longer the replacement can be deferred, the lower the present value of its cost.
- **Direct Cost Risk (DCR)** – If equipment fails during the deferral period, intervention costs may be incrementally higher for collateral damage and planning, procurement, and scheduling inefficiencies (overtime, emergency hiring, contract premiums, etc.). This cost risk increases as equipment condition degrades over time.
- **Lost Generation Risk (LGR)** – Equipment failure may also result in longer outages and, thus, more lost generation than if replaced on a planned basis. LGR also increases as equipment condition degrades over time.
- **Lost Efficiency Opportunity (LEO)** – Some equipment replacements (turbine runners, transformers and generator windings) reduce efficiency losses. Deferring replacement results in a lost opportunity to capture increased generation from higher efficiency equipment.

Present Value Cost of Intervention at Different Points in Time



The **Total Cost** is the present value sum of replacement costs, risk costs and the opportunity cost of deferring a replacement resulting in efficiency gains (Lost Efficiency Opportunity). The cost minimum on this curve is the point at which financial risk is forecasted to begin growing faster than the benefit of investment deferral and represents the optimum time to forecast replacement to minimize lifecycle cost.

Assumptions Used in Modeling

Assumption	Value	Source	Comment
Discount rate	12.0 percent (Base Case) 8.0 percent (All Sensitivities)	BPA Finance BPA Generating Assets	10 percent real 6 percent real
Inflation rate	1.9 percent	BPA Finance	Average annual rate, 20-yr forecast
Forward energy price curve	20-yr, by month, HLH, LLH, flat $36 – Levelized Energy Value $25 – Capacity Value	BPA Power Services Resource Program	Includes spot prices and a component for long-term firm capacity consistent with rate case demand rate.
Equipment cost	Varies by equipment type	FCRPS hydro program	Based on industry cost data
Real cost escalation	0 percent	BPA Finance	Global Insight
Failure curves	Varies by equipment type	BPA Generating Assets	Based on industry data for certain equipment
Outage duration for LGR	Varies by equipment type	FCRPS hydro program	Based on industry experience
Environment and safety	Risk	BPA Generating Assets	Treats all high risk items as “must do”
Value of avoided CO2	$35/ton	BPA Corporate Strategy	Based on Presidential Directive
Alternative resource for hydro lost generation	Natural gas-fired Combined-Cycle Combustion Turbine	BPA Agency Asset Management	0.48 tons of CO2 per MWh of generation

For this strategy, each equipment component is evaluated in yearly time steps and forecasted for refurbishment/replacement if it meets either of the following criteria:

- First, if its condition places it into a high risk category for safety or environment.
- Second, if financial risk costs are increasing faster than investment deferral benefits, i.e., the equipment component is at the cost minimum.

Once the equipment component is selected for investment, its condition resets to 10 at the end of the investment period. Its condition then begins to degrade at the identified degradation rate.

If an annual funding limitation is defined, then the prioritization proceeds as follows:

- Committed projects proceed as scheduled;
- High risk safety and environmental projects are selected as previously described;
- Financial risk driven projects are selected as described until an annual funding limitation is reached, after which investment in equipment in which financial risk is increasing the least is deferred until the following year, where it is re-evaluated using the same prioritization logic.

When funding constraints are applied, Total Cost for the system (system cost) increases because new investments are deferred past their cost minima.

In an effort to validate and improve the quality of condition assessment, failure curve and replacement cost data, the FCRPS is undergoing or considering the following initiatives:

hydroAMP:

As part of the Asset Investment Excellence Initiative, the FCRPS is investigating improvements in the implementation of the hydroAMP program. One such improvement is potentially moving the ownership of hydroAMP condition assessment from the plants to a centralized FCRPS team. This team will be charged with either inputting the data themselves based on information from the plants or quality assuring the data that is entered by the plants in order to eliminate some of the inherent biases that exist with each plant's interpretation of the assessment guides.

Failure Curves:

Partnering with the Army Corps of Engineers Risk Management Center, the FCRPS participated in a series of Expert Opinion Elicitations to build a new set of failure curves for a number of powertrain and critical ancillary components. As more empirical data becomes available, Bayesian updating techniques will be used to continually improve the curves. The results of the expert elicitations will be vetted in 2016 and incorporated in subsequent asset strategies.

Replacement Costs:

An initiative is underway to update the cost algorithms used for long term planning purposes. Current cost algorithms are based on single-variate regression models. The new algorithms will expand on the existing capability where appropriate.

The Hydro Investment Plan covers forecasted O&M, the committed investment program, and new investments to maintain and improve the reliability of electrical and mechanical plant equipment.

Because O&M costs are primarily labor related, and the currently committed investment program is already vetted and underway, the focus of the Hydro Investment Plan is on new investments not yet decided upon.

The O&M program forecast and risk based approach to identifying new capital investments reasonably cover costs necessary for addressing business continuity requirements, including sparing strategies for critical equipment.

Future costs are included between FY17-FY19 for the construction of a third unit at Black Canyon.

Costs Not Considered in the Strategy

The Grand Coulee 115kV, 230kV, and 500kV switchyards have been identified by Reclamation and BPA as a source of potentially high risk. A scoping study is currently underway to determine the extent to which the switchyards need to be modernized. The funding source and possible cost share of this investment between BPA Power Services and BPA Transmission Services has yet to be determined. Currently, the work is estimated to occur after 2020.

Costs associated with expansion opportunities (with the exception of the Third Unit at Black Canyon) are excluded from this strategy, including the costs associated with uprating Grand Coulee units 19 through 21 and the Grand Coulee Drumgate Maintenance Structure. The reliability investment costs for units 19 through 21, which represent about two-thirds of the total investment cost, are included.

Fish facilities funded under Columbia River Fish Mitigation are aging. Initial costs of these facilities are funded under appropriations and reimbursed by BPA. Costs for repairs and replacements of these facilities are not covered in this strategy.

Cost also excluded are those for rebuilding or replacing dam safety civil features which are typically funded through appropriations, a share of which is reimbursed by BPA. For the focus period of this strategy, the exclusion of costs for dam safety is not expected to materially affect the funding need forecast. However, as the hydro system continues to age, anticipating funding needs for dam safety will require more explicit attention in future strategies.

5. BASELINE CAPITAL PROGRAM LEVEL

$200 MILLION ANNUAL INVESTMENT (2016 DOLLARS)

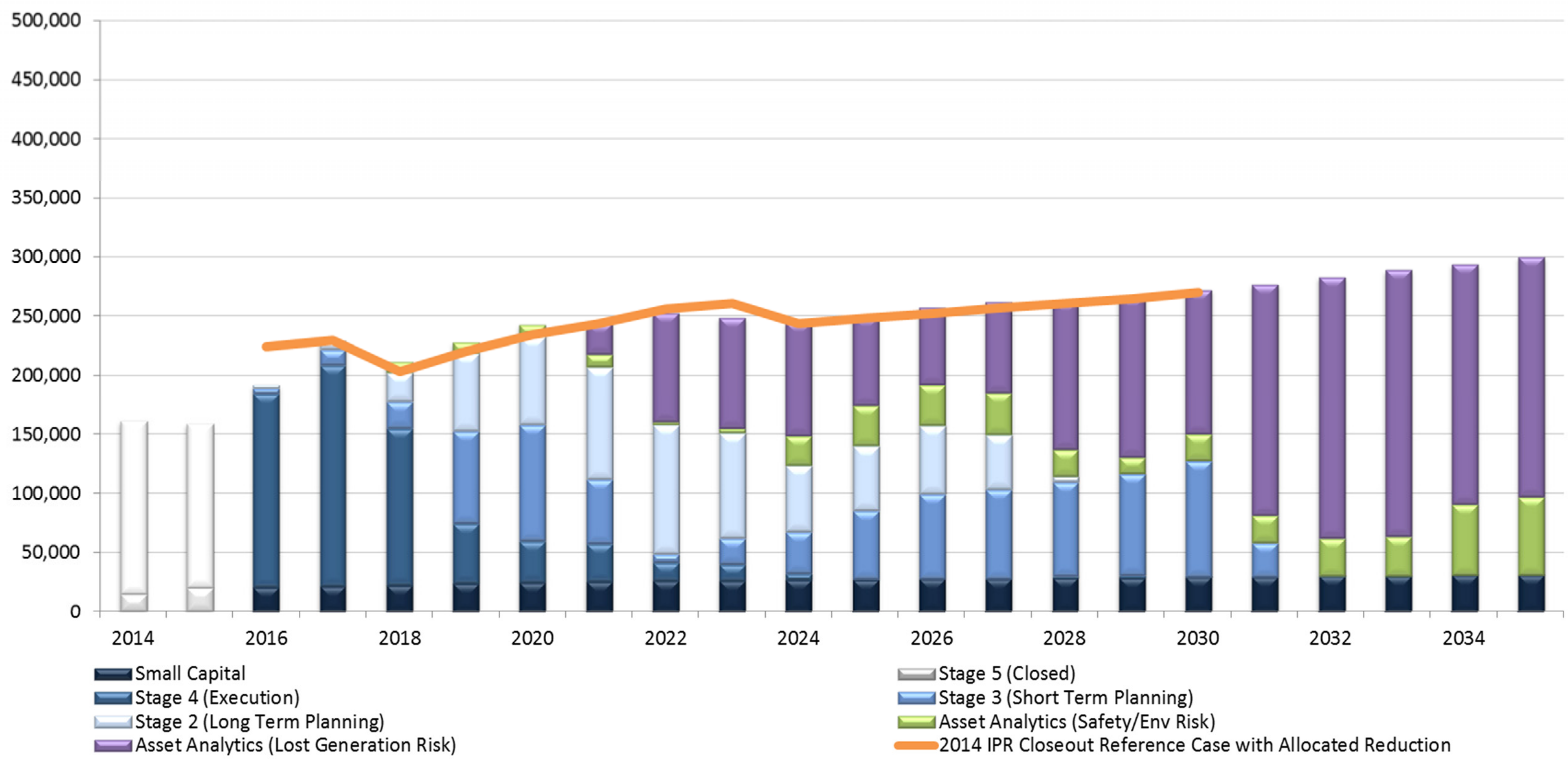
Baseline Program - $200M Annual Capital Investment Level (2016 Dollars)

Capital Forecast

Modeling funding constraints in this strategy have little effect on the 2016 – 2021 program. Nearly all available funding is committed during this period, so there is limited ability to turn these projects off without significant negative financial consequences. Funding constraints affect the number of projects that can be undertaken 5 to 20 years into the future to mitigate forecasted growth in risk.

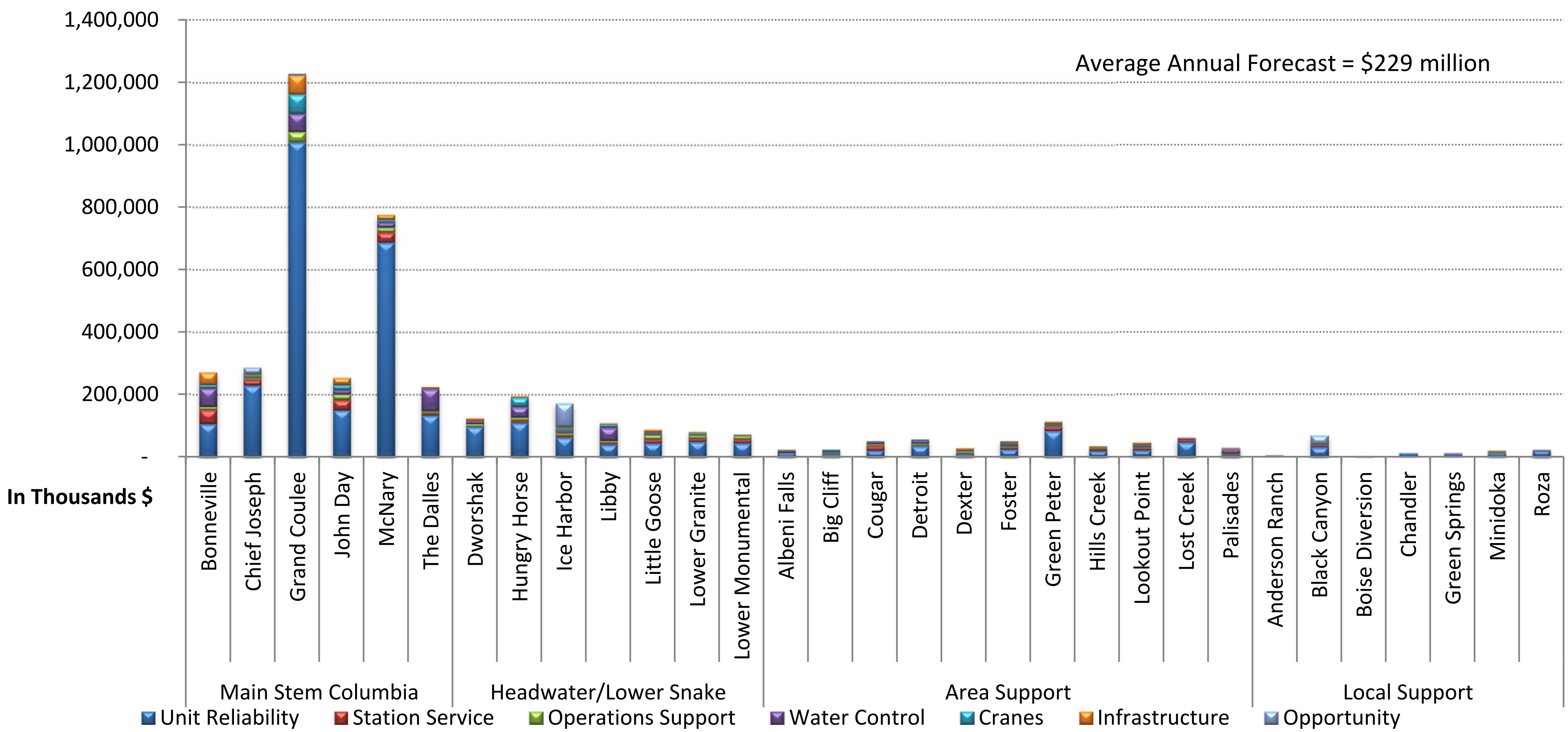
The following graph shows modeling results when constrained to the 2014 IPR Closeout at a 12% discount rate. It is assumed that 50 percent of the unallocated reduction in Capital is allocated to the FCRPS hydro program, resulting in approximately a $200 million program in real 2016 dollars.

Capital Program Forecast (2014-2035) Nominal $000s



Baseline Program - $200M Annual Capital Investment Level (2016 Dollars)

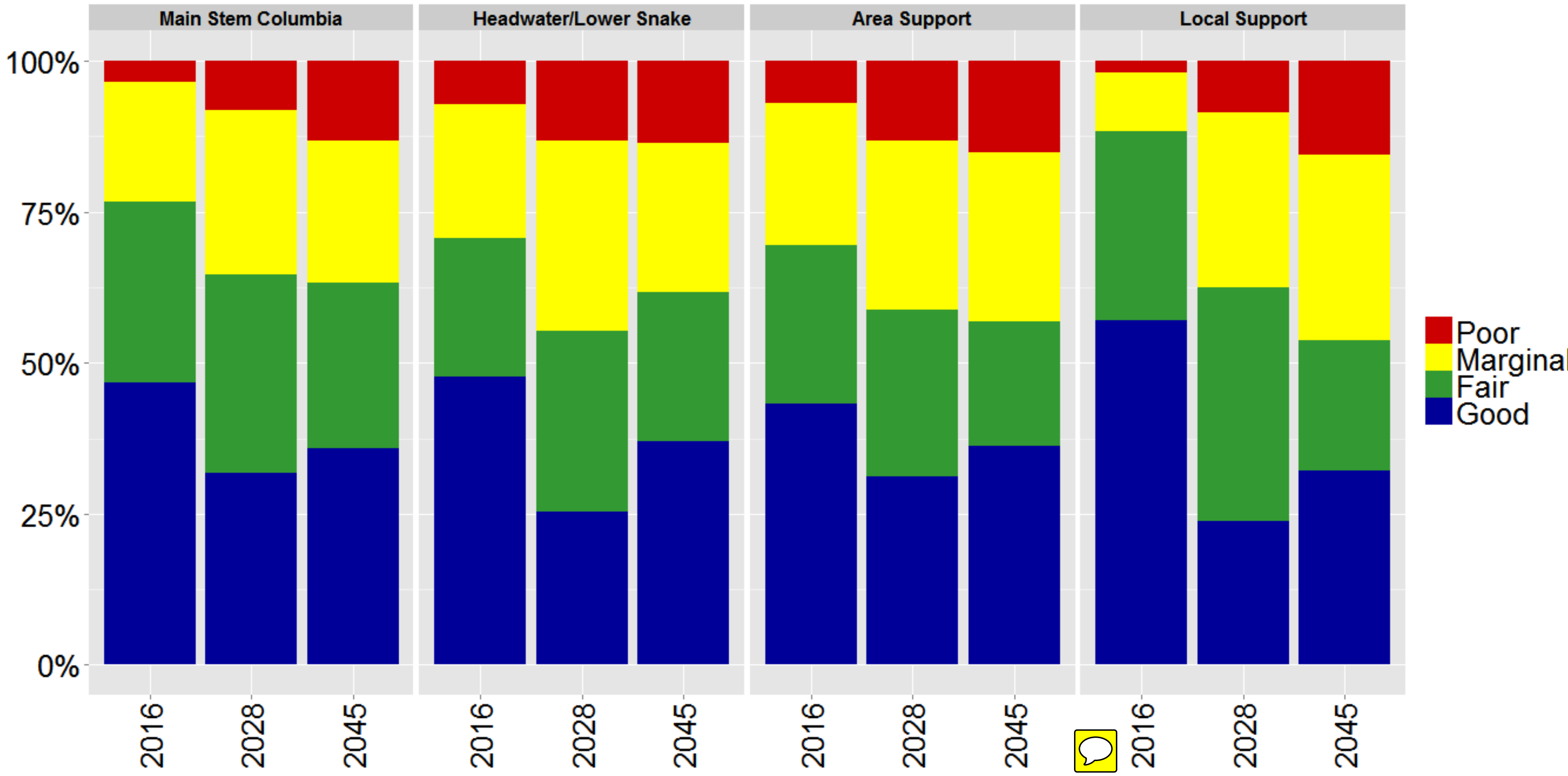
Large Capital Forecast by Plant (FY16-FY35)



54 percent of the funding over the next 15 years is targeted at Grand Coulee and McNary, two of the highest risk plants in the FCRPS, representing 65 percent of total Lost Generation Risk. More than half of total investment is targeted at Unit Reliability investments across the system.

Baseline Program - $200M Annual Capital Investment Level (2016 Dollars)

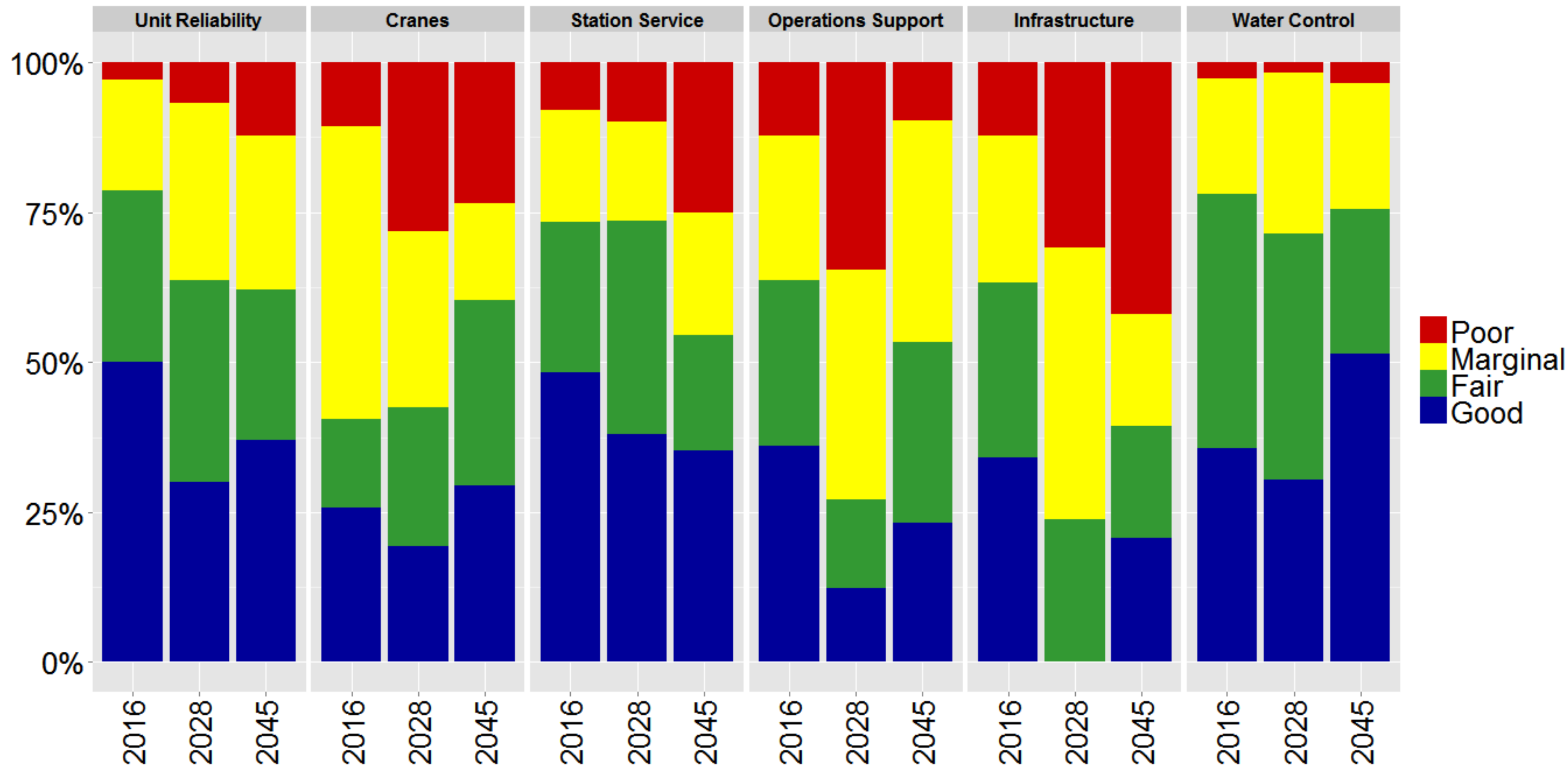
Condition by Strategic Class



The $200M baseline program cannot keep up with degrading condition for a majority of the plants. Between now and 2028, the condition of the system declines across all strategic classes. By 2045, only the Headwater and Lower Snake plants see an increase in the percentage of assets in Good or Fair condition.

Baseline Program - $200M Annual Capital Investment Level (2016 Dollars)

Condition by Equipment Category



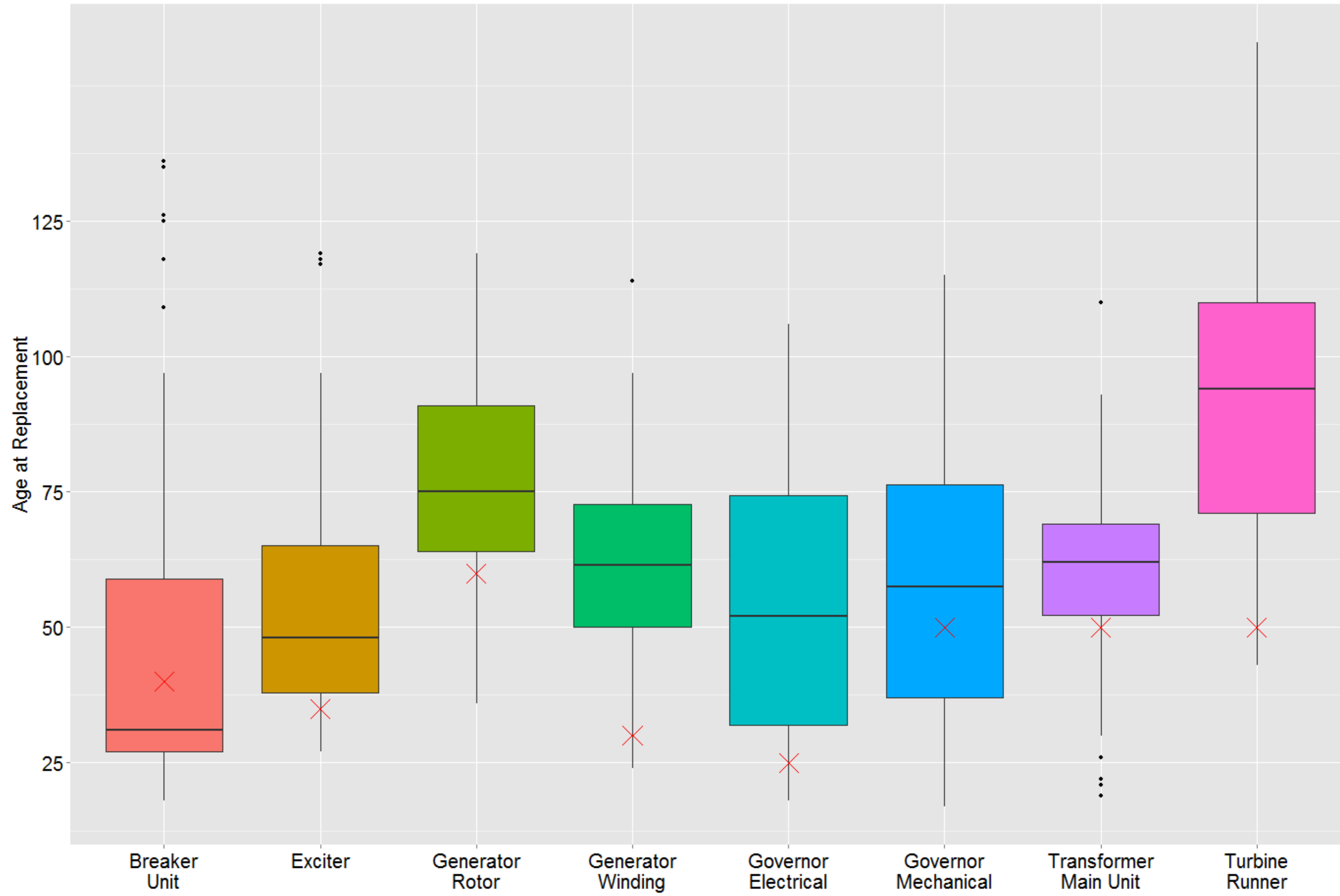
With the majority of available funding going towards Unit Reliability improvements, the overall condition of Cranes, Station Service, Operations Support and Infrastructure decline. Although many of these assets do not impact revenue generation directly, long term neglect will result in higher risk and real costs that are not currently captured in this strategy.

Age at Replacement

Understanding the age of the asset population at replacement can be a useful measure in determining the adequacy of a replacement program. Generally speaking, high risk assets should be replaced very near their design lives while it may be tolerable for less risky assets to operate beyond their design lives. Overall, a vast majority of the powertrain assets are forecast to be replaced well beyond their design lives. This will likely result in an increasing maintenance burden and increasing forced and scheduled outages in order to keep the assets in operation until their identified replacement years defined by the Baseline Program level. The impacts on Operations and Maintenance costs are expected to be minimal in the near and mid-term but will continue to increase as the assets age and the number of assets in marginal and poor condition grows over time.

Baseline Program - $200M Annual Capital Investment Level (2016 Dollars)

Age at Replacement



At the baseline program, the majority of the powertrain components are replaced well after their service life (denoted by the red “X” in chart above).

Baseline Program - $200M Annual Capital Investment Level (2016 Dollars)

Financial Risk Matrix in 2028

Likelihood	Insignificant < $ 10K	Minor $ 10K to $ 100K	Moderate $ 100K to $ 1 M	Major $ 1 M to $ 10 M	Extreme > $ 10 M
Almost Certain	5 Station Service 54 Operations Support	63 Unit Reliability 2 Cranes 19 Station Service 55 Operations Support 3 Water Control	65 Unit Reliability 6 Cranes 29 Station Service 65 Operations Support 36 Infrastructure 6 Water Control	101 Unit Reliability 12 Cranes 59 Station Service 5 Operations Support 3 Infrastructure	5 Unit Reliability 2 Station Service
Likely	3 Station Service 61 Operations Support	174 Unit Reliability 2 Cranes 13 Station Service 27 Operations Support 3 Water Control	87 Unit Reliability 46 Cranes 17 Station Service 25 Operations Support 18 Infrastructure 8 Water Control	200 Unit Reliability 33 Cranes 50 Station Service 2 Operations Support 1 Infrastructure	22 Unit Reliability 2 Station Service
Possible	13 Operations Support 5 Infrastructure	79 Unit Reliability 26 Station Service 29 Operations Support 18 Infrastructure 7 Water Control	257 Unit Reliability 30 Cranes 22 Station Service 22 Operations Support 26 Infrastructure 68 Water Control	464 Unit Reliability 22 Cranes 61 Station Service 3 Operations Support 4 Infrastructure 16 Water Control	90 Unit Reliability 1 Water Control
Unlikely	2 Operations Support	27 Station Service 7 Operations Support 4 Infrastructure 2 Water Control	85 Unit Reliability 7 Cranes 6 Station Service 5 Operations Support 7 Infrastructure 5 Water Control	277 Unit Reliability 16 Station Service 1 Infrastructure 3 Water Control	91 Unit Reliability
Rare	6 Station Service 5 Operations Support 1 Infrastructure	94 Unit Reliability 64 Station Service 7 Operations Support 4 Infrastructure 7 Water Control	568 Unit Reliability 27 Cranes 117 Station Service 20 Operations Support 25 Infrastructure 71 Water Control	823 Unit Reliability 26 Cranes 87 Station Service 1 Operations Support 2 Infrastructure 19 Water Control	211 Unit Reliability 4 Cranes 14 Station Service 5 Water Control

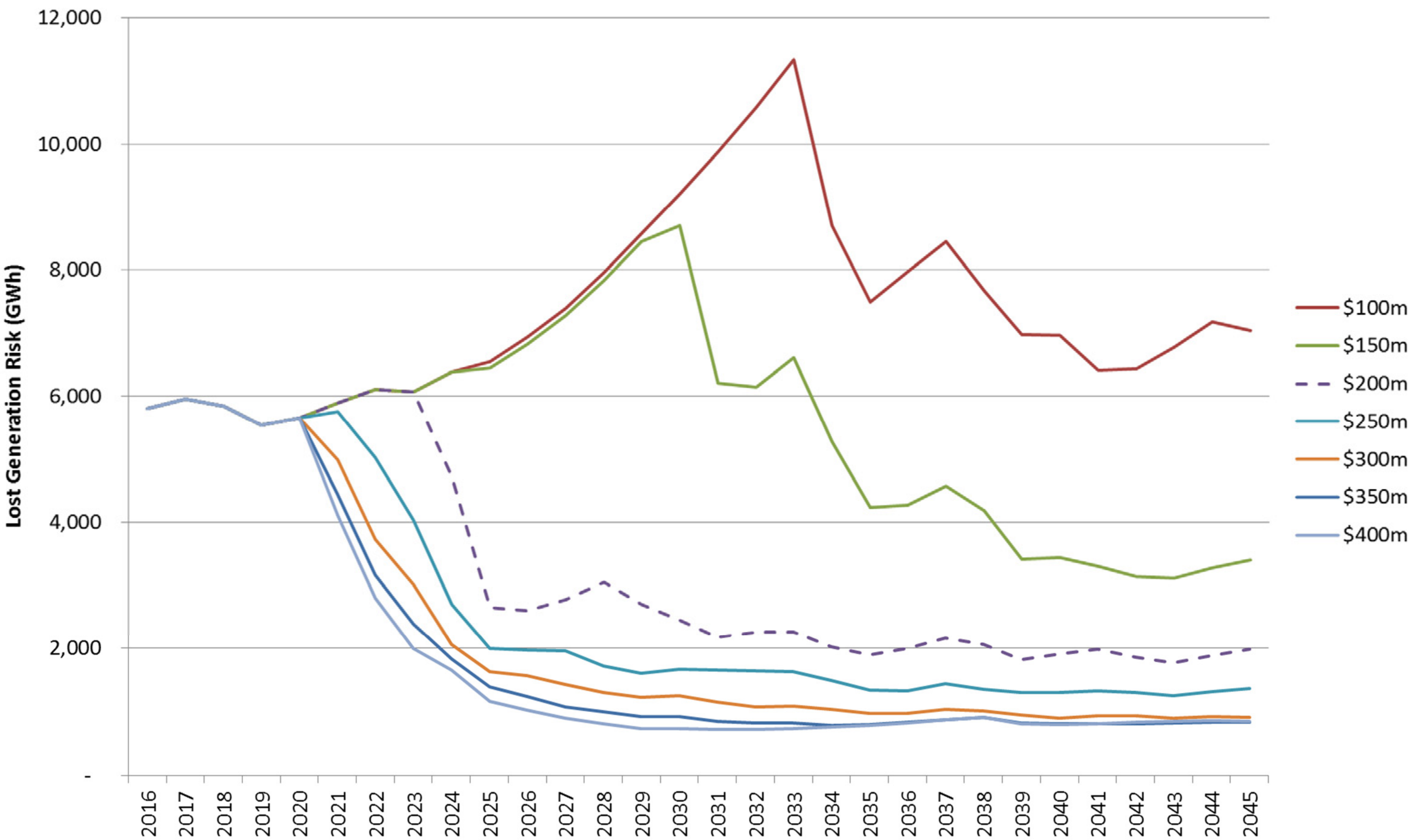
Consequence

Condition: 0 – 10

Risk Level	Low	Medium	High

Baseline Program - $200M Annual Capital Investment Level (2016 Dollars)

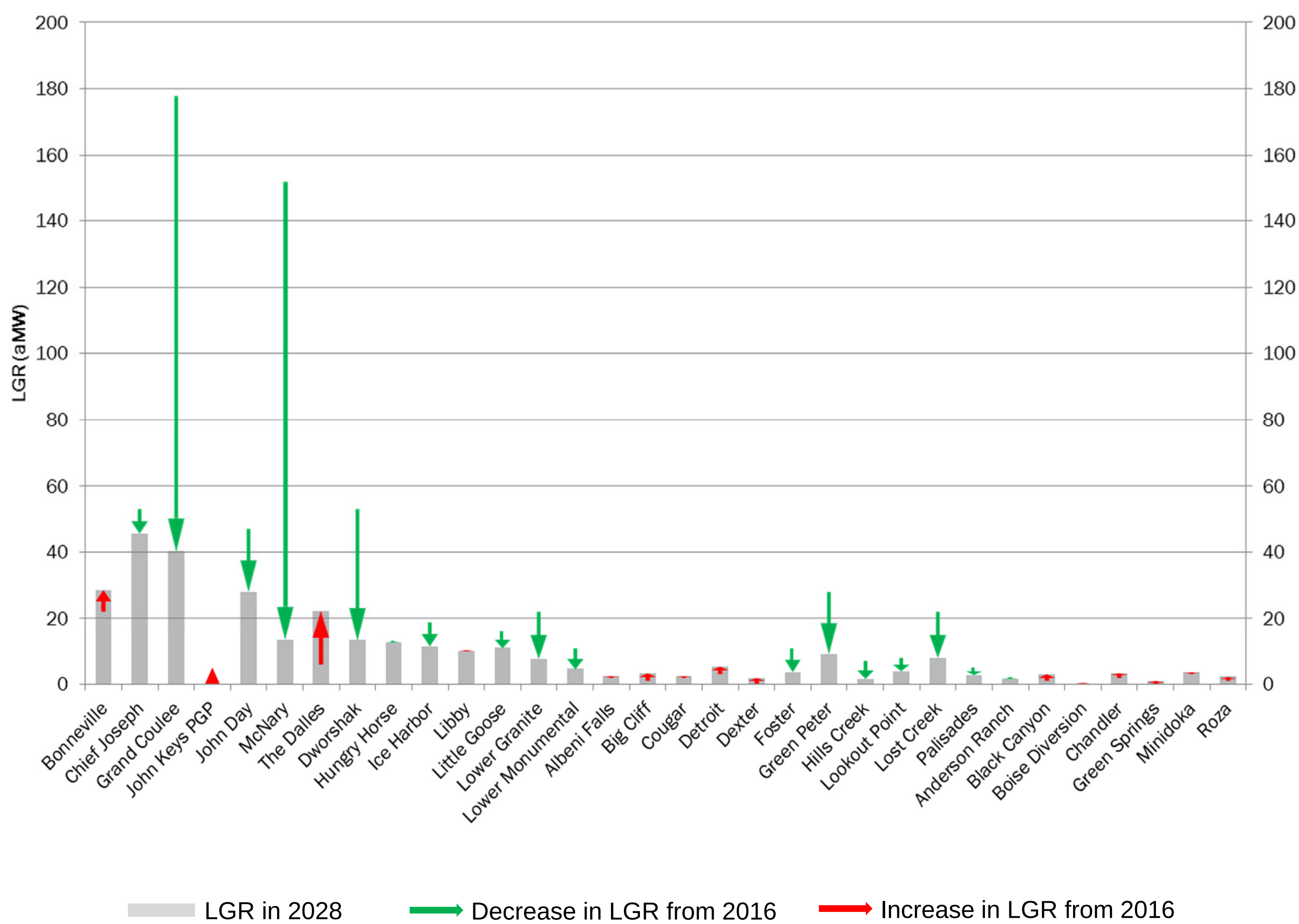
Lost Generation Risk



From current levels, the $200M Baseline Program is able to reduce lost generation risk by about 50 percent by 2028. The majority of the reduction is achieved through the electrical replacements in the Left and Right Powerhouses at Grand Coulee as well as generator replacements on units 19-21 in the Third Powerhouse. Runner replacements at McNary also account for a significant portion of the risk reduction. Compared to the Baseline Program, higher funding levels continue to deliver significant risk reduction. Lower program levels leave little room for investment at plants outside of Grand Coulee and McNary. Risk grows significantly across the system until these investments complete and funds are available for other plants.

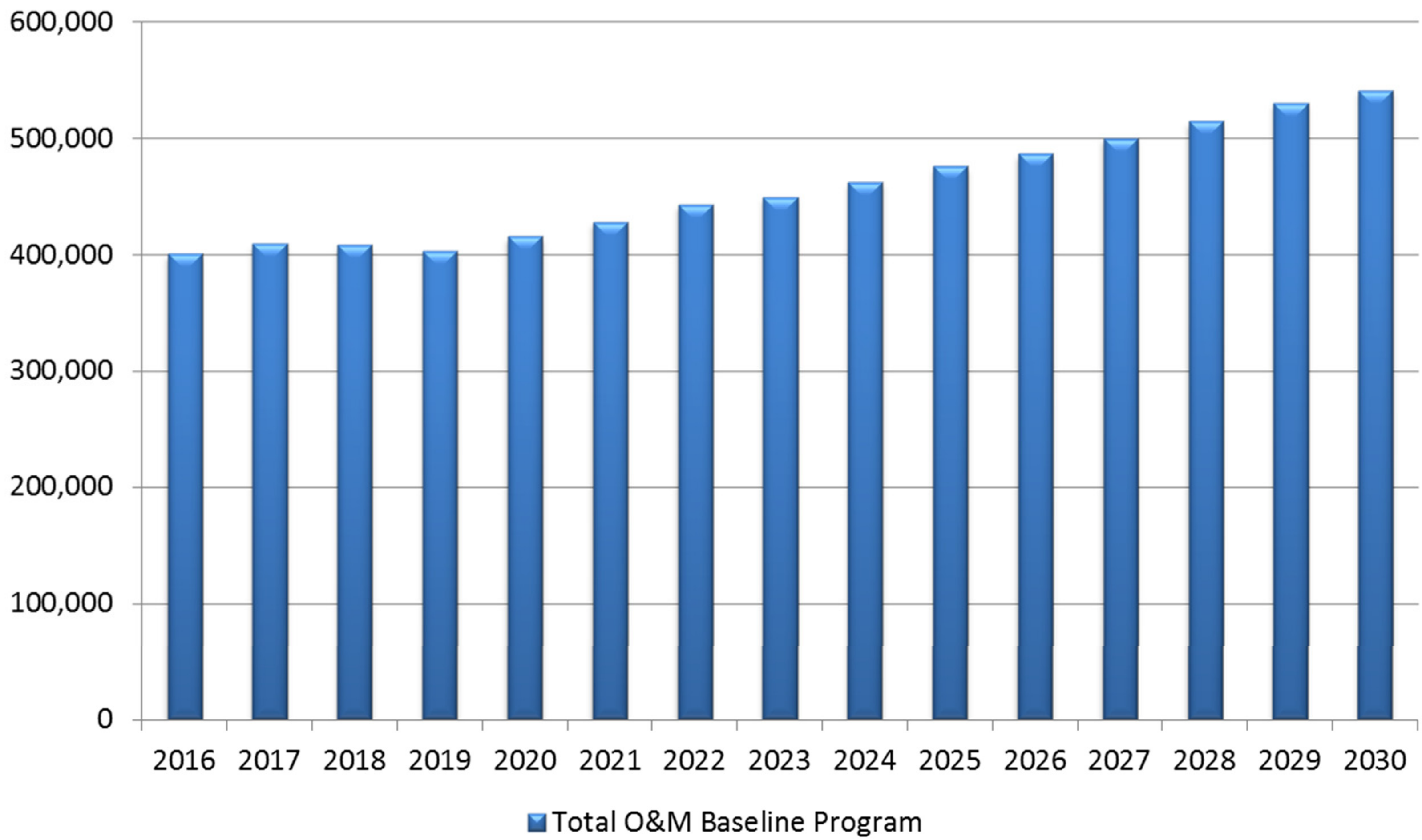
Baseline Program - $200M Annual Capital Investment Level (2016 Dollars)

Lost Generation Risk by Plant in 2028



Baseline Program - $200M Annual Capital Investment Level (2016 Dollars)

Total O&M Forecast



O&M Reference Case derived from 2014 IPR. 2016 levels are not yet finalized.

Over the next twenty years, the $200 million Baseline Program invests primarily in Grand Coulee and McNary, two of the highest risk plants in the FCRPS. In doing so, lost generation risk is reduced by more than fifty percent compared to today's level. However, the Baseline Program is insufficient in addressing condition degradation across the system, with the percentage of assets in marginal and poor condition continuing to increase into the future. By 2028, forty percent of the assets are forecast to be in Marginal or Poor condition compared to twenty-five percent today. The Baseline Program level does not provide adequate funding to reverse the trend in declining condition. Many assets will also be forced to operate well beyond their design lives, posing a significant maintenance burden in the future in order to keep assets in service until their replacement dates. Furthermore, the number of high risk assets on the financial risk matrix is projected to increase from 340 to 704.

The Baseline Program primarily focuses on investments in Unit Reliability for the next twenty years. This results in many critical ancillary, operations support and infrastructure assets to be forced to operate well beyond their design lives. Although these assets do not have immediate or direct impacts on generation, the risk of extremely high cost, low probability events increases along with the potential for inefficient operation.

6. RECOMMENDED CAPITAL PROGRAM LEVEL

$300 MILLION ANNUAL INVESTMENT (2016 DOLLARS)

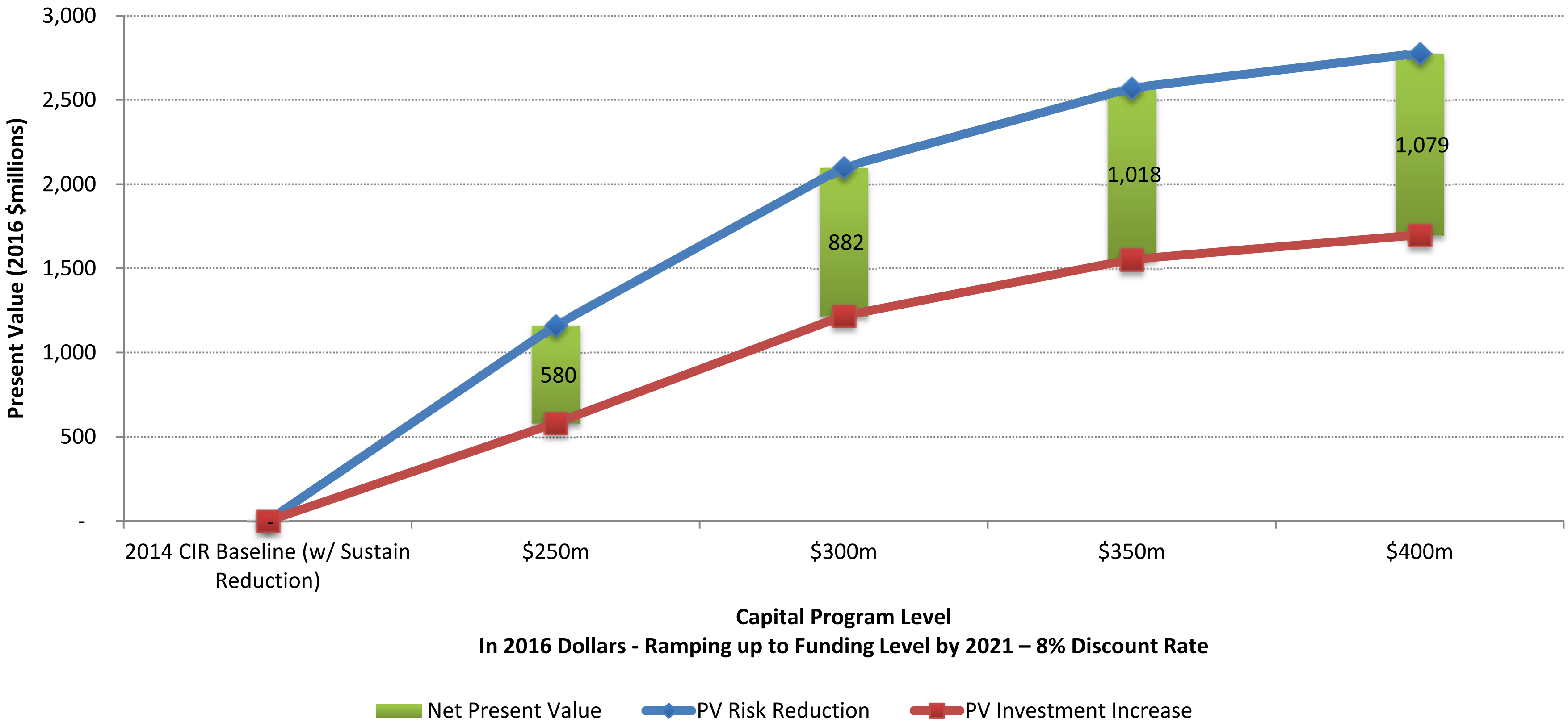
Other Funding Constraint Scenarios

Funding constraints require that some investments are delayed beyond their cost minimum, resulting in higher risk and Total Cost for the system. For the strategy, the impacts of various higher funding levels and their associated reduction in risk were analyzed. Several sensitivities were run to show the impact of reduced funding constraints on condition, age and lost generation risk. Funding for 2016-2017 is identical for all scenarios, with each then ramping up to the identified funding level from 2018-2021 after which the constraint is held constant in real terms for the remainder of the 50-year study period.

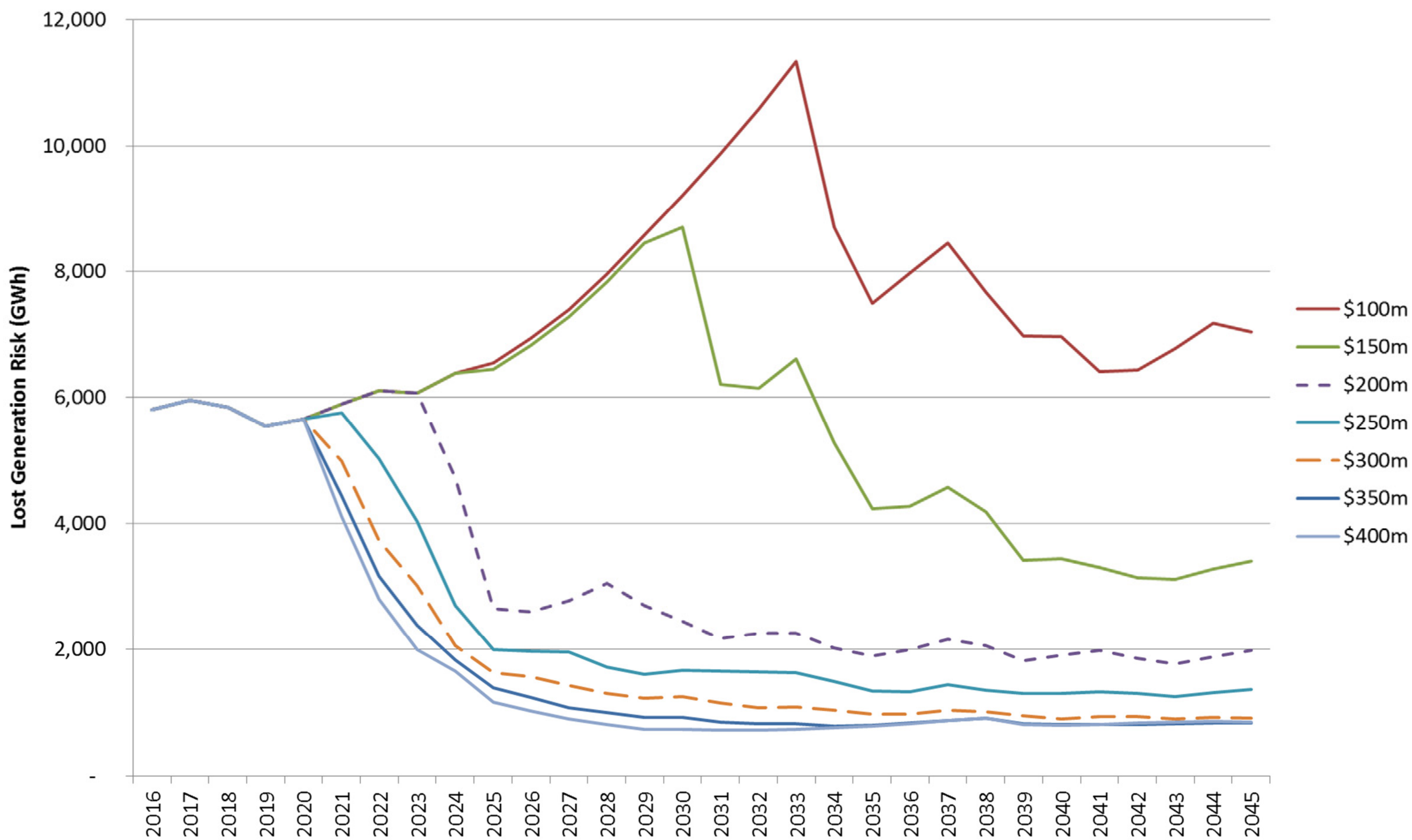
Resulting from customer requests from the previous Capital Investment Review, the following sensitivities, including the Baseline Program, use an 8% discount rate. A series of discount rate sensitivities are included in Appendix C.

Net Present Value of Different Funding Levels

The net present value (NPV) of higher funding scenarios increases fairly dramatically up to an investment level of $300 million per year (2016 dollars), after which it increases more slowly. For a $300 million scenario, the present value of costs increases by $1.25 billion, but the present value of risk reduction increases by more than $2.1 billion, resulting in a NPV of $882 million relative to the current 2014 IPR Baseline (with Allocated Sustain Reductions).



Lost Generation Risk Forecast for Different Funding Levels

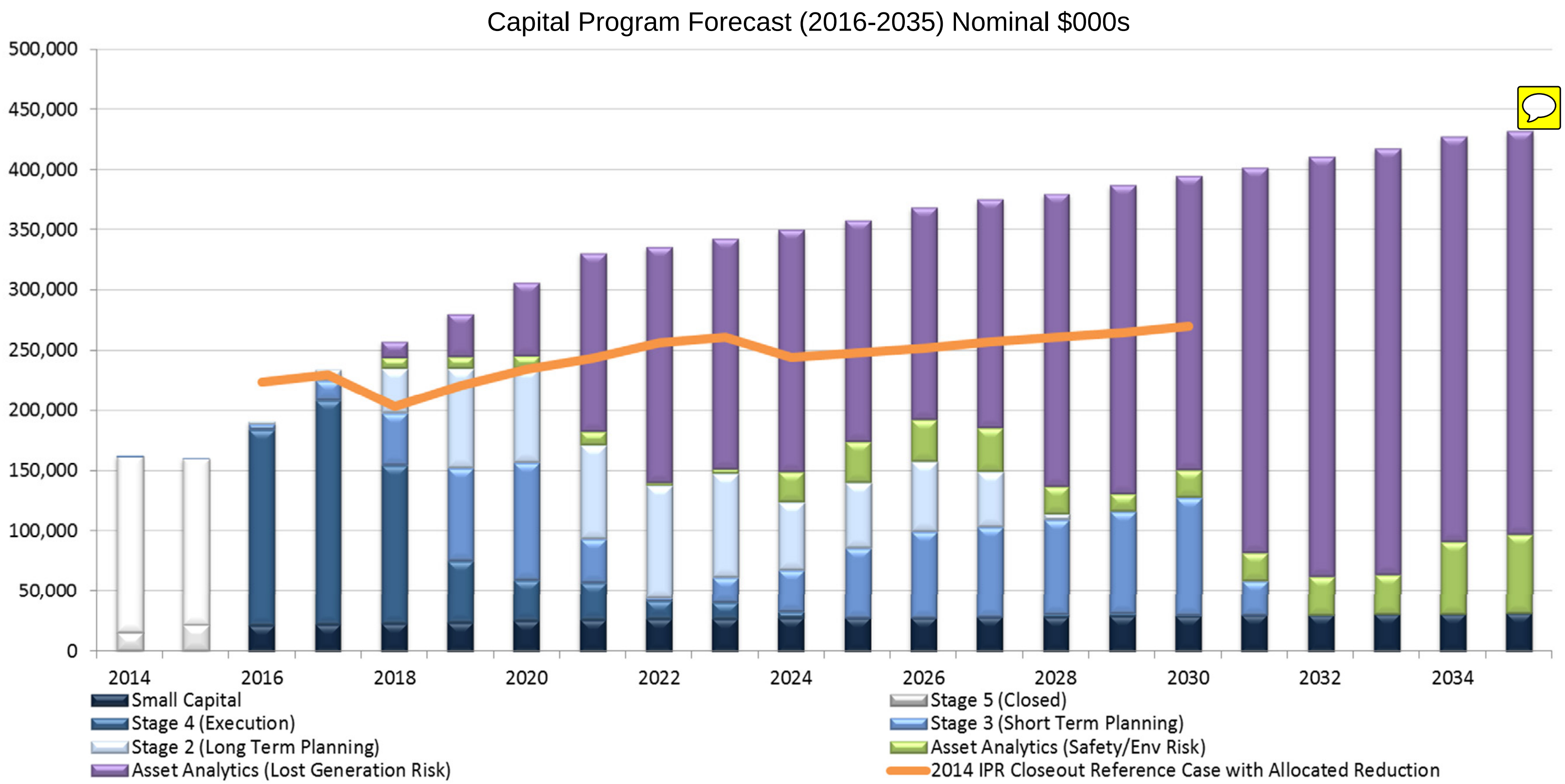


Investing beyond the $300 million program level results in diminishing returns for Lost Generation Risk reduction, especially in the out-years. Investment levels higher than $300 million deliver additional risk reduction benefits for about twenty years before converging in 2038.

The $300 million annual budget constraint has been identified as the recommended program level for the following reasons:

- Reduces lost generation risk by more than 1,500 GWh compared to the 2014 IPR Closeout levels (with Allocated Reduction) by 2028.
- Maintains or even improves the percentage of equipment in Good or Fair condition by 2028 and beyond.
- Keeps ancillary and non-generation impacting assets in acceptable condition.
- Brings investment levels in the FCRPS closer to the industry benchmark median.
- Incremental Capital Spend over the Baseline Program is forecasted to have little to no impact on rates, actually resulting in a slightly lower rate in 2028 than the Baseline Program.
- Achievable from a resource, outage and execution standpoint *with* longer-term or stronger funding commitment.

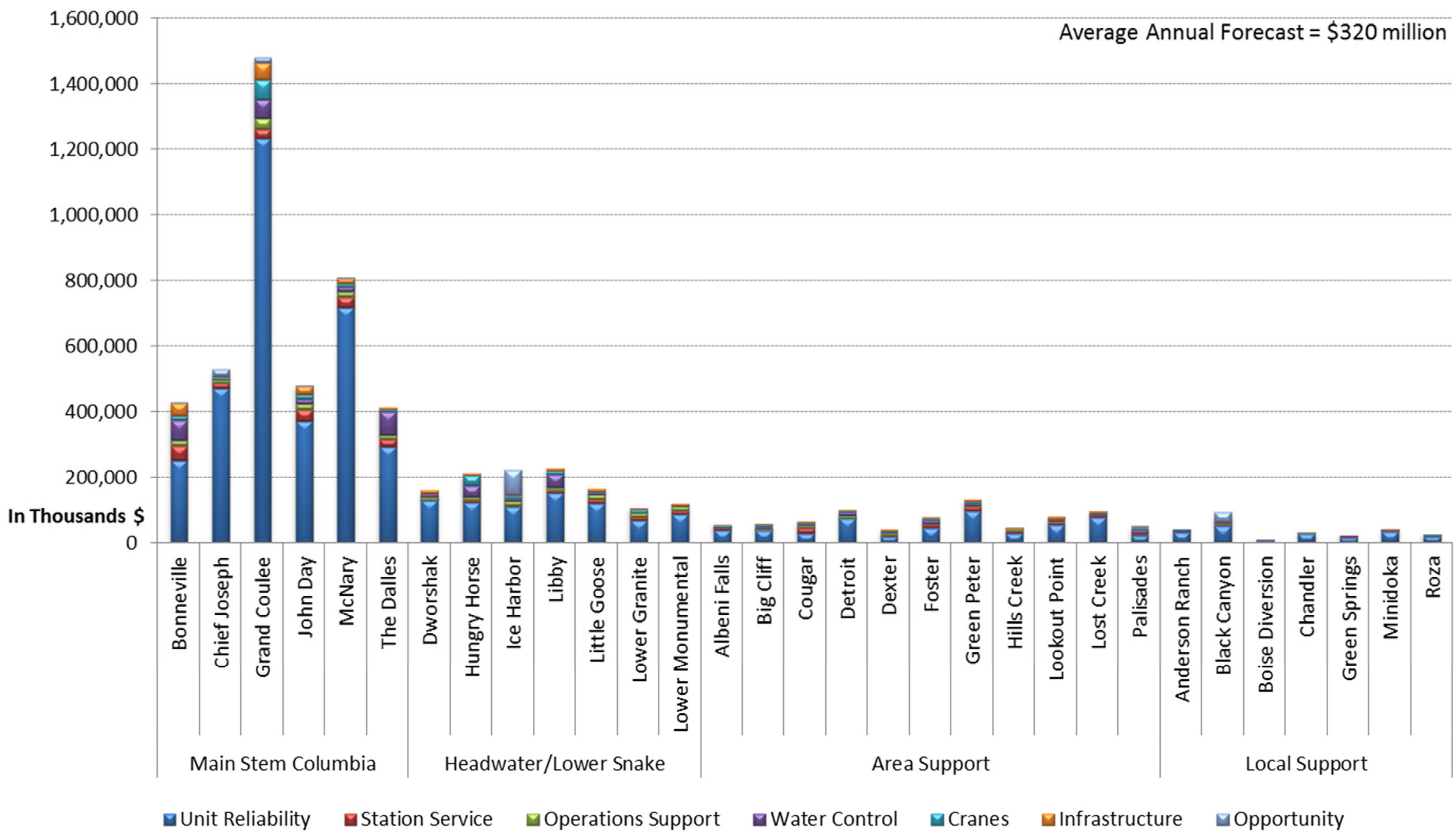
Although not recommended in this Hydro Asset Strategy, higher funding levels should continue to be evaluated in future strategies to determine their feasibility as it does appear that further benefits exist.



The Capital Program ramps up to a $300 million annual investment level by 2021 and is then held constant in 2016 dollars. Given the $300 million annual constraint, the modelling suggests that it is optimal to expend the full budget for the entirety of the study period.

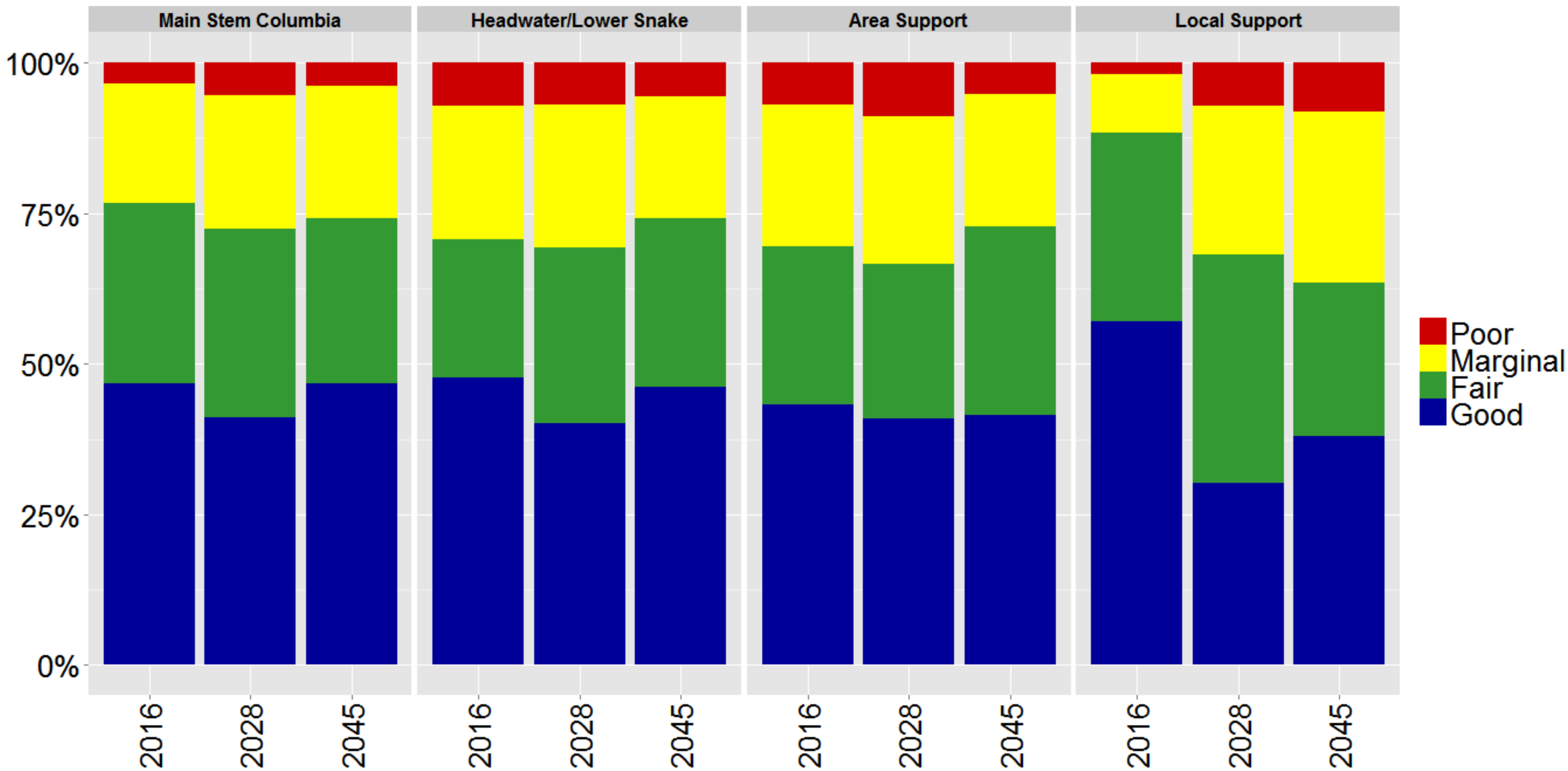
Recommended Program Level - $300M Annual Capital Investment Level (2016 Dollars)

Capital Forecast by Plant (FY16-FY35)



Recommended Program Level - $300M Annual Capital Investment Level (2016 Dollars)

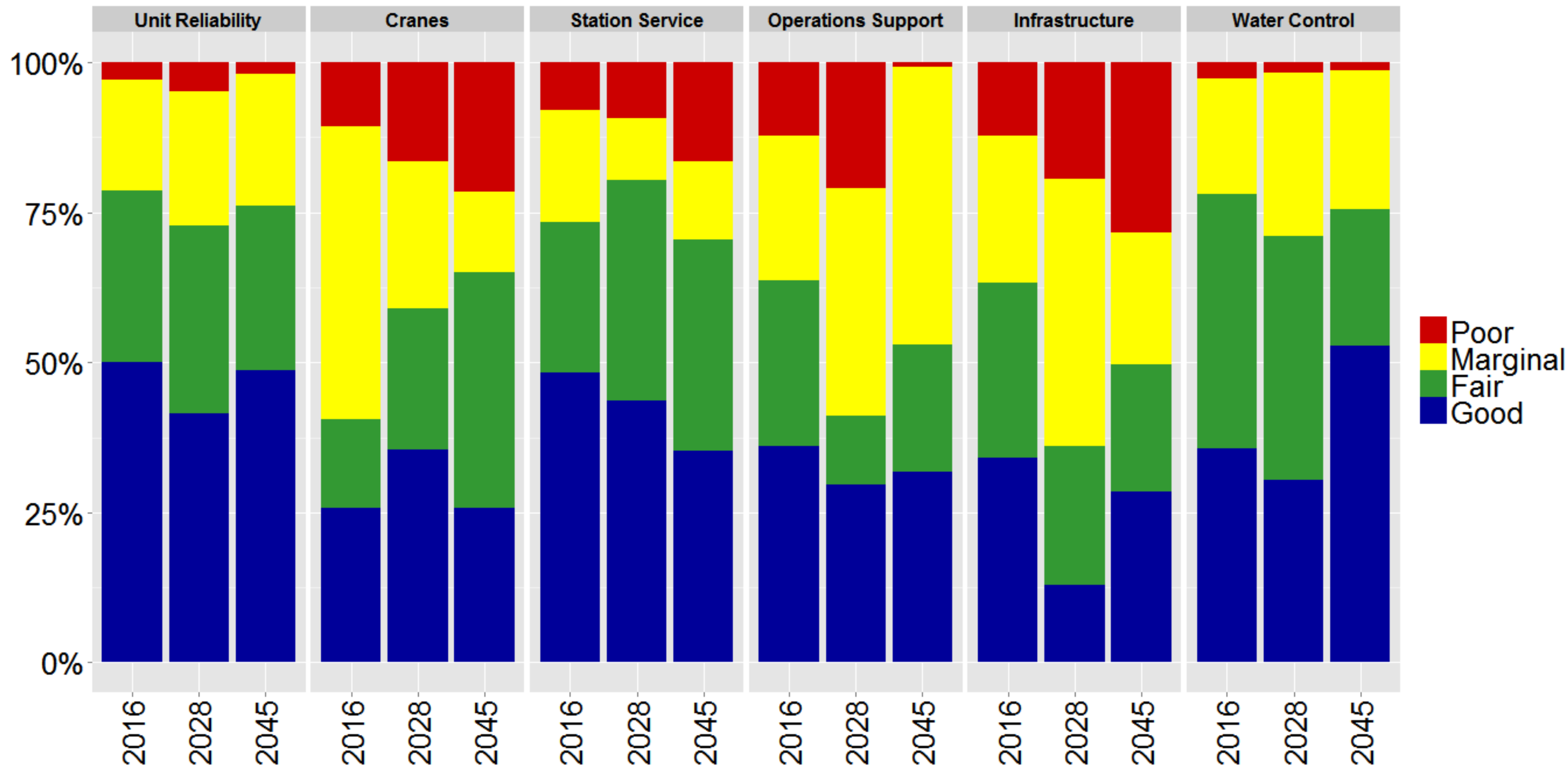
Condition by Strategic Class



Compared to the baseline program, a $300 million program effectively sustains or improves condition for three of the four strategic classes into the future. The overall condition for Local Support declines, but reaches a new steady-state level of condition similar to the other strategic classes.

Recommended Program Level - $300M Annual Capital Investment Level (2016 Dollars)

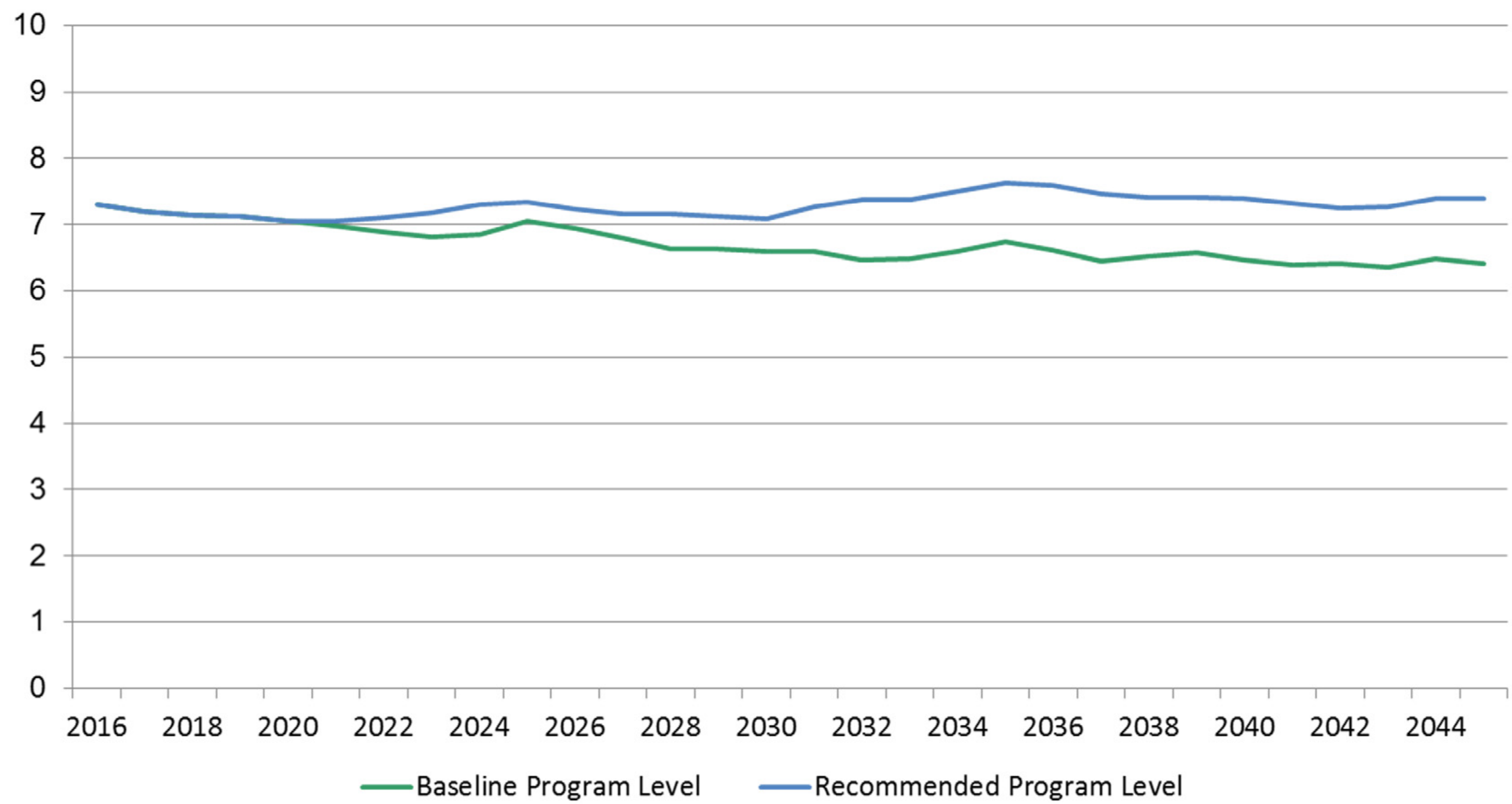
Condition by Equipment Category



In addition to sustaining the condition of the generating assets over the study period, critical supporting equipment types are not allowed to degrade as much as in the baseline scenario. This reduces the risk of low probability but extreme consequence events and also limits the risk of inefficient operations that are not explicitly quantified in this strategy.

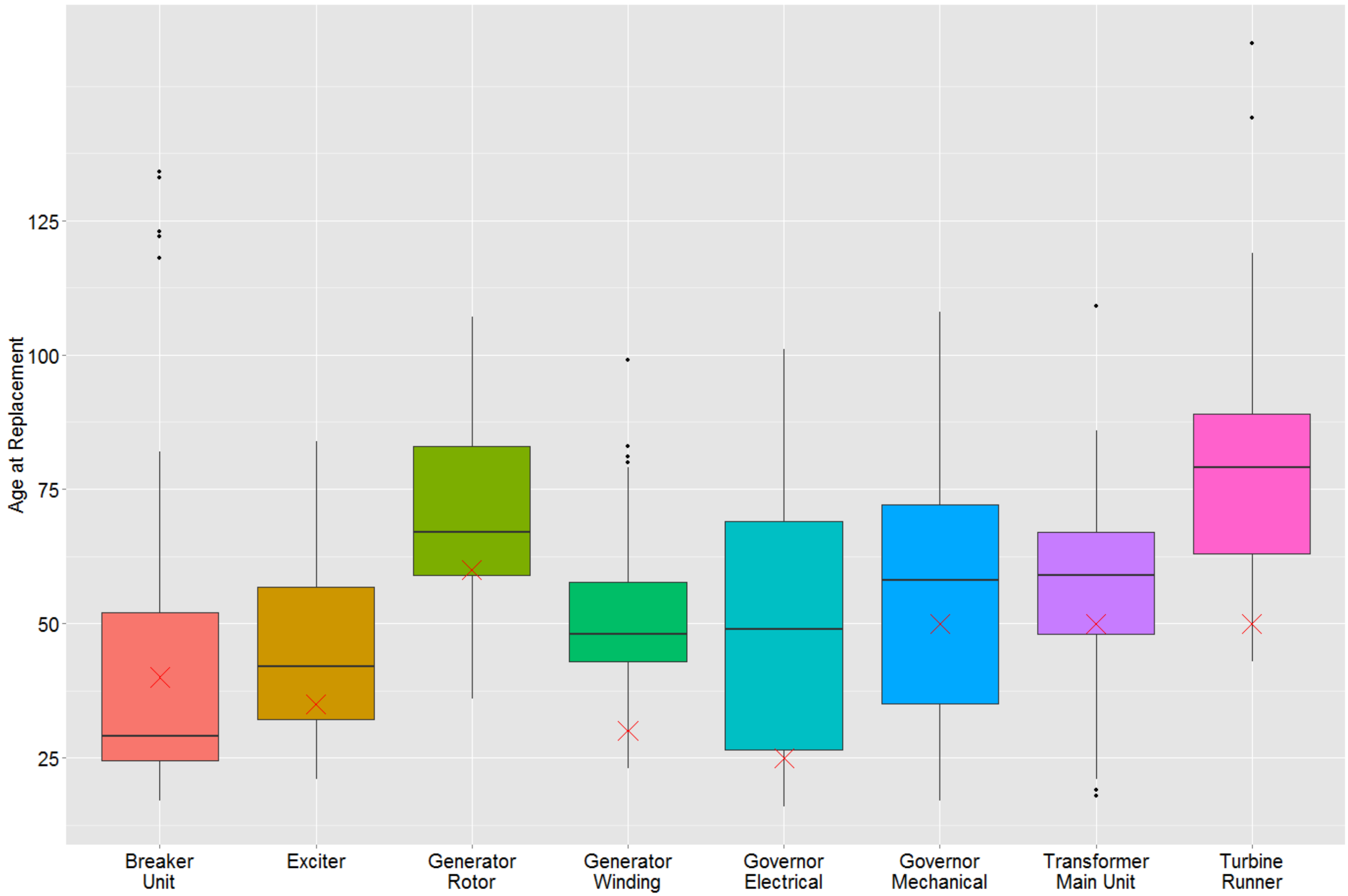
Recommended Program Level - $300M Annual Capital Investment Level (2016 Dollars)

Capacity Weighted Average Condition – All Equipment



The capacity weighted average condition for all equipment stays relatively stable around a 7.4 at the Recommended Program. In comparison, the Baseline Program has an overall downward trend toward a condition 6.4.

Age at Replacement



In the $300 million Recommended Program, the median age at replacement for powertrain equipment is considerably closer to the components' respective design lives. Specifically, about three-quarters of Turbine Runners are scheduled to be replaced by the age of 80. In the Baseline Program, less than half of the Turbine Runner population had been replaced by that age.

Recommended Program Level - $300M Annual Capital Investment Level (2016 Dollars)

Financial Risk Map in 2028

Baseline Funding

Likelihood	Insignificant < $ 10K	Minor $ 10K to $ 100K	Moderate $ 100K to $ 1 M	Major $ 1 M to $ 10 M	Extreme > $ 10 M
Almost Certain	5 Station Service 54 Operations Support	44 Unit Reliability 2 Cranes 19 Station Service 49 Operations Support	47 Unit Reliability 6 Cranes 29 Station Service 34 Operations Support 36 Infrastructure 2 Water Control	9 Unit Reliability 3 Cranes 5 Station Service 5 Operations Support 3 Infrastructure	
Likely	3 Station Service 61 Operations Support	148 Unit Reliability 2 Cranes 13 Station Service 25 Operations Support 2 Water Control	75 Unit Reliability 45 Cranes 15 Station Service 24 Operations Support 18 Infrastructure 3 Water Control	97 Unit Reliability 18 Cranes 27 Station Service 2 Operations Support 1 Infrastructure	4 Unit Reliability
Possible	13 Operations Support 5 Infrastructure	59 Unit Reliability 26 Station Service 29 Operations Support 18 Infrastructure 7 Water Control	230 Unit Reliability 30 Cranes 21 Station Service 22 Operations Support 26 Infrastructure 64 Water Control	443 Unit Reliability 20 Cranes 19 Station Service 3 Operations Support 4 Infrastructure 10 Water Control	64 Unit Reliability 1 Water Control
Unlikely	2 Operations Support	27 Station Service 7 Operations Support 4 Infrastructure 2 Water Control	85 Unit Reliability 7 Cranes 6 Station Service 5 Operations Support 7 Infrastructure 5 Water Control	277 Unit Reliability 15 Station Service 1 Infrastructure 3 Water Control	88 Unit Reliability
Rare	6 Station Service 5 Operations Support 1 Infrastructure	159 Unit Reliability 64 Station Service 15 Operations Support 4 Infrastructure 11 Water Control	625 Unit Reliability 28 Cranes 120 Station Service 52 Operations Support 25 Infrastructure 84 Water Control	1039 Unit Reliability 52 Cranes 207 Station Service 1 Operations Support 2 Infrastructure 25 Water Control	263 Unit Reliability 4 Cranes 18 Station Service 5 Water Control

Consequence

Risk Level	Low	Medium	High

$300 Million

Likelihood	Insignificant < $ 10K	Minor $ 10K to $ 100K	Moderate $ 100K to $ 1 M	Major $ 1 M to $ 10 M	Extreme > $ 10 M
Almost Certain	5 Station Service 38 Operations Support	44 Unit Reliability 1 Cranes 19 Station Service 23 Operations Support	35 Unit Reliability 1 Cranes 29 Station Service 11 Operations Support 21 Infrastructure 2 Water Control	1 Unit Reliability 3 Operations Support	
Likely	3 Station Service 61 Operations Support	148 Unit Reliability 2 Cranes 13 Station Service 25 Operations Support 2 Water Control	38 Unit Reliability 43 Cranes 14 Station Service 24 Operations Support 18 Infrastructure 3 Water Control	26 Unit Reliability 4 Cranes 2 Operations Support 1 Infrastructure	
Possible	13 Operations Support 5 Infrastructure	59 Unit Reliability 26 Station Service 29 Operations Support 18 Infrastructure 7 Water Control	186 Unit Reliability 30 Cranes 17 Station Service 22 Operations Support 26 Infrastructure 64 Water Control	224 Unit Reliability 11 Cranes 4 Station Service 3 Operations Support 4 Infrastructure 10 Water Control	30 Unit Reliability 1 Water Control
Unlikely	2 Operations Support	27 Station Service 7 Operations Support 4 Infrastructure 2 Water Control	85 Unit Reliability 7 Cranes 6 Station Service 5 Operations Support 7 Infrastructure 5 Water Control	222 Unit Reliability 12 Station Service 1 Infrastructure 3 Water Control	85 Unit Reliability
Rare	6 Station Service 21 Operations Support 1 Infrastructure	159 Unit Reliability 1 Cranes 64 Station Service 41 Operations Support 4 Infrastructure 11 Water Control	718 Unit Reliability 35 Cranes 125 Station Service 75 Operations Support 40 Infrastructure 84 Water Control	1392 Unit Reliability 78 Cranes 257 Station Service 3 Operations Support 5 Infrastructure 25 Water Control	304 Unit Reliability 4 Cranes 18 Station Service 5 Water Control

Consequence

Risk Level	Low	Medium	High

Condition: 0 – 10

In 2028, the $300 million scenario has less than half the number of assets in the High Risk category compared to the Baseline scenario (136 vs 328).

Recommended Program Level - $300M Annual Capital Investment Level (2016 Dollars)

Safety Risk Map in 2028

Baseline Funding

Likelihood \ Consequence	No impact	Impact to on-site environment (simple remediation)	Limited impact off-site (localized remediation required)	Detrimental impact on- or off-site (long-term remediation required)	Detrimental or catastrophic impact off-site (mitigation impossible)
Almost Certain	71 Unit Reliability 7 Cranes 43 Station Service 39 Operations Support 39 Infrastructure	28 Unit Reliability 14 Station Service 11 Operations Support	1 Unit Reliability 4 Cranes 1 Station Service 92 Operations Support 2 Water Control		
Likely	246 Unit Reliability 43 Cranes 38 Station Service 44 Operations Support 19 Infrastructure	74 Unit Reliability 14 Station Service 4 Operations Support	4 Unit Reliability 22 Cranes 6 Station Service 59 Operations Support 5 Water Control	5 Operations Support	
Possible	581 Unit Reliability 30 Cranes 37 Station Service 11 Operations Support 53 Infrastructure	130 Unit Reliability 22 Station Service 10 Operations Support	85 Unit Reliability 20 Cranes 7 Station Service 32 Operations Support 13 Water Control	14 Operations Support	69 Water Control
Unlikely	223 Unit Reliability 7 Cranes 15 Station Service 12 Infrastructure	205 Unit Reliability 28 Station Service	22 Unit Reliability 5 Station Service 12 Operations Support 3 Water Control	2 Operations Support	7 Water Control
Rare	1178 Unit Reliability 27 Cranes 244 Station Service 32 Infrastructure	492 Unit Reliability 97 Station Service 1 Operations Support	416 Unit Reliability 57 Cranes 74 Station Service 45 Operations Support 16 Water Control	27 Operations Support	109 Water Control

Risk Level	Low	Medium	High

$300 Million

Likelihood \ Consequence	No impact	Impact to on-site environment (simple remediation)	Limited impact off-site (localized remediation required)	Detrimental impact on- or off-site (long-term remediation required)	Detrimental or catastrophic impact off-site (mitigation impossible)
Almost Certain	60 Unit Reliability 1 Cranes 38 Station Service 27 Operations Support 21 Infrastructure	20 Unit Reliability 14 Station Service 6 Operations Support	1 Cranes 1 Station Service 42 Operations Support 2 Water Control		
Likely	191 Unit Reliability 43 Cranes 11 Station Service 44 Operations Support 19 Infrastructure	19 Unit Reliability 13 Station Service 4 Operations Support	2 Unit Reliability 6 Cranes 6 Station Service 59 Operations Support 5 Water Control	5 Operations Support	
Possible	355 Unit Reliability 30 Cranes 19 Station Service 11 Operations Support 53 Infrastructure	65 Unit Reliability 21 Station Service 10 Operations Support	79 Unit Reliability 11 Cranes 7 Station Service 32 Operations Support 13 Water Control	14 Operations Support	69 Water Control
Unlikely	193 Unit Reliability 7 Cranes 13 Station Service 12 Infrastructure	179 Unit Reliability 27 Station Service	20 Unit Reliability 5 Station Service 12 Operations Support 3 Water Control	2 Operations Support	7 Water Control
Rare	1500 Unit Reliability 33 Cranes 296 Station Service 12 Operations Support 50 Infrastructure	646 Unit Reliability 100 Station Service 6 Operations Support	427 Unit Reliability 85 Cranes 74 Station Service 95 Operations Support 16 Water Control	27 Operations Support	109 Water Control

Condition: 0 (top) to 10 (bottom)

Risk Level	Low	Medium	High

In 2028, the $300 million scenario has less than half the number of assets in the High Risk Safety category compared to the Baseline scenario (51 vs 105).

Recommended Program Level - $300M Annual Capital Investment Level (2016 Dollars)

Environmental Risk Map in 2028

Baseline Funding

Likelihood	No or minor injury, first aid	Treatment by medical professional	Lost time Accident - temporary disability	Lost Time Accident - permanent disability/fatality	Multiple fatalities
Almost Certain	71 Unit Reliability 43 Station Service 39 Operations Support 24 Infrastructure 2 Water Control	28 Unit Reliability 7 Cranes 14 Station Service 21 Operations Support 15 Infrastructure	1 Unit Reliability 4 Cranes 1 Station Service 82 Operations Support		
Likely	255 Unit Reliability 38 Station Service 44 Operations Support 6 Infrastructure	65 Unit Reliability 43 Cranes 14 Station Service 29 Operations Support 13 Infrastructure 5 Water Control	4 Unit Reliability 22 Cranes 6 Station Service 34 Operations Support	5 Operations Support	
Possible	662 Unit Reliability 37 Station Service 11 Operations Support 40 Infrastructure	49 Unit Reliability 30 Cranes 22 Station Service 41 Operations Support 13 Infrastructure 13 Water Control	7 Unit Reliability 20 Cranes 7 Station Service 9 Operations Support	6 Operations Support	78 Unit Reliability 69 Water Control
Unlikely	391 Unit Reliability 15 Station Service 11 Infrastructure	37 Unit Reliability 7 Cranes 28 Station Service 11 Operations Support 1 Infrastructure 3 Water Control	22 Unit Reliability 5 Station Service 1 Operations Support	2 Operations Support	7 Water Control
Rare	1328 Unit Reliability 244 Station Service 14 Infrastructure 3 Water Control	342 Unit Reliability 27 Cranes 97 Station Service 30 Operations Support 18 Infrastructure 13 Water Control	219 Unit Reliability 57 Cranes 74 Station Service 3 Operations Support	40 Operations Support	197 Unit Reliability 109 Water Control

Consequence

Risk Level	Low	Medium	High

$300 Million

Likelihood	No or minor injury, first aid	Treatment by medical professional	Lost time Accident - temporary disability	Lost Time Accident - permanent disability/fatality	Multiple fatalities
Almost Certain	60 Unit Reliability 38 Station Service 27 Operations Support 15 Infrastructure 2 Water Control	20 Unit Reliability 1 Cranes 14 Station Service 13 Operations Support 6 Infrastructure	1 Cranes 1 Station Service 35 Operations Support		
Likely	193 Unit Reliability 11 Station Service 44 Operations Support 6 Infrastructure	17 Unit Reliability 43 Cranes 13 Station Service 29 Operations Support 13 Infrastructure 5 Water Control	2 Unit Reliability 6 Cranes 6 Station Service 34 Operations Support	5 Operations Support	
Possible	404 Unit Reliability 19 Station Service 11 Operations Support 40 Infrastructure	16 Unit Reliability 30 Cranes 21 Station Service 41 Operations Support 13 Infrastructure 13 Water Control	1 Unit Reliability 11 Cranes 7 Station Service 9 Operations Support	6 Operations Support	78 Unit Reliability 69 Water Control
Unlikely	354 Unit Reliability 13 Station Service 11 Infrastructure	18 Unit Reliability 7 Cranes 27 Station Service 11 Operations Support 1 Infrastructure 3 Water Control	20 Unit Reliability 5 Station Service 1 Operations Support	2 Operations Support	7 Water Control
Rare	1696 Unit Reliability 296 Station Service 12 Operations Support 23 Infrastructure 3 Water Control	450 Unit Reliability 33 Cranes 100 Station Service 38 Operations Support 27 Infrastructure 13 Water Control	230 Unit Reliability 85 Cranes 74 Station Service 50 Operations Support	40 Operations Support	197 Unit Reliability 109 Water Control

Consequence

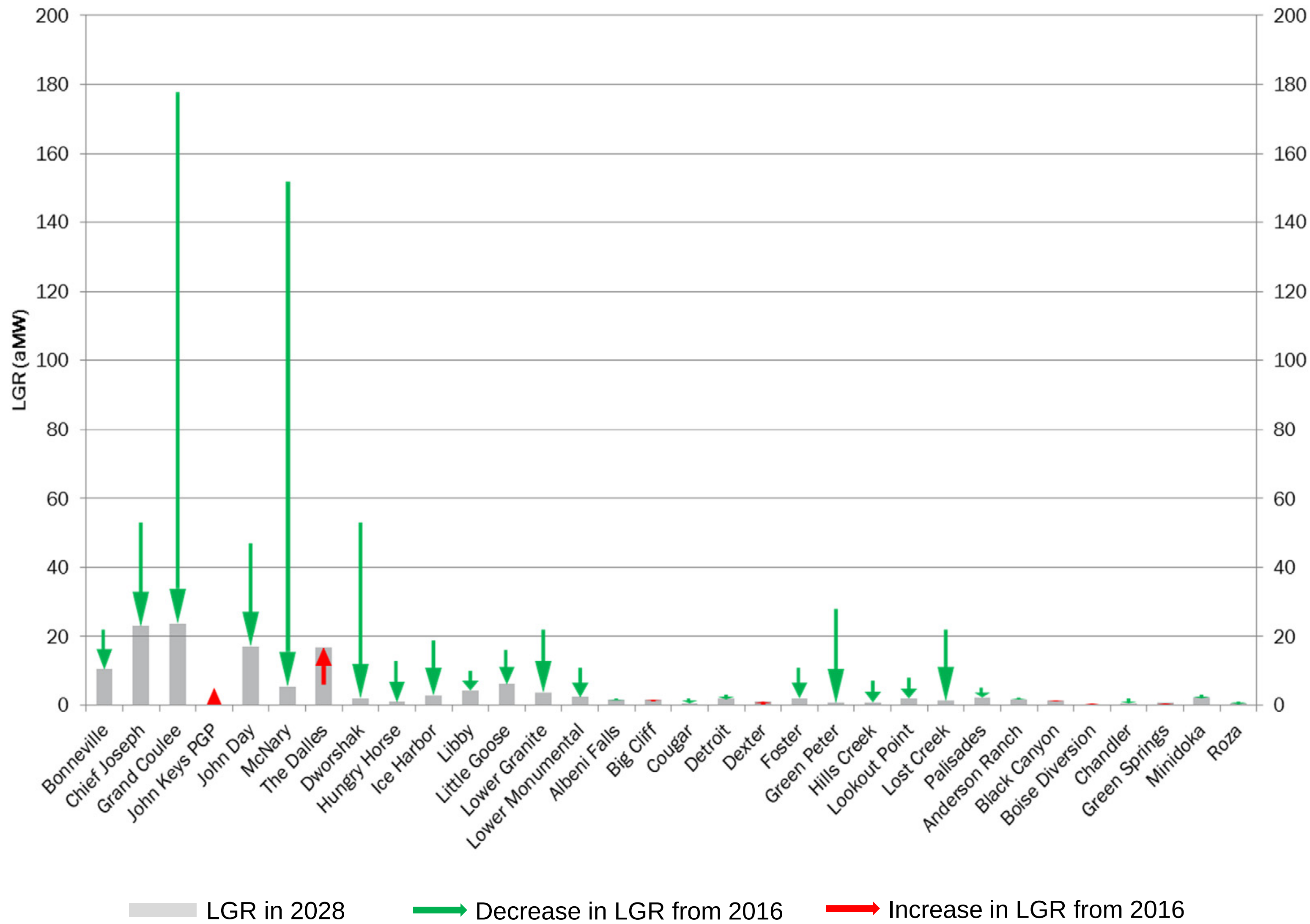
Risk Level	Low	Medium	High

Condition: 0 – 10

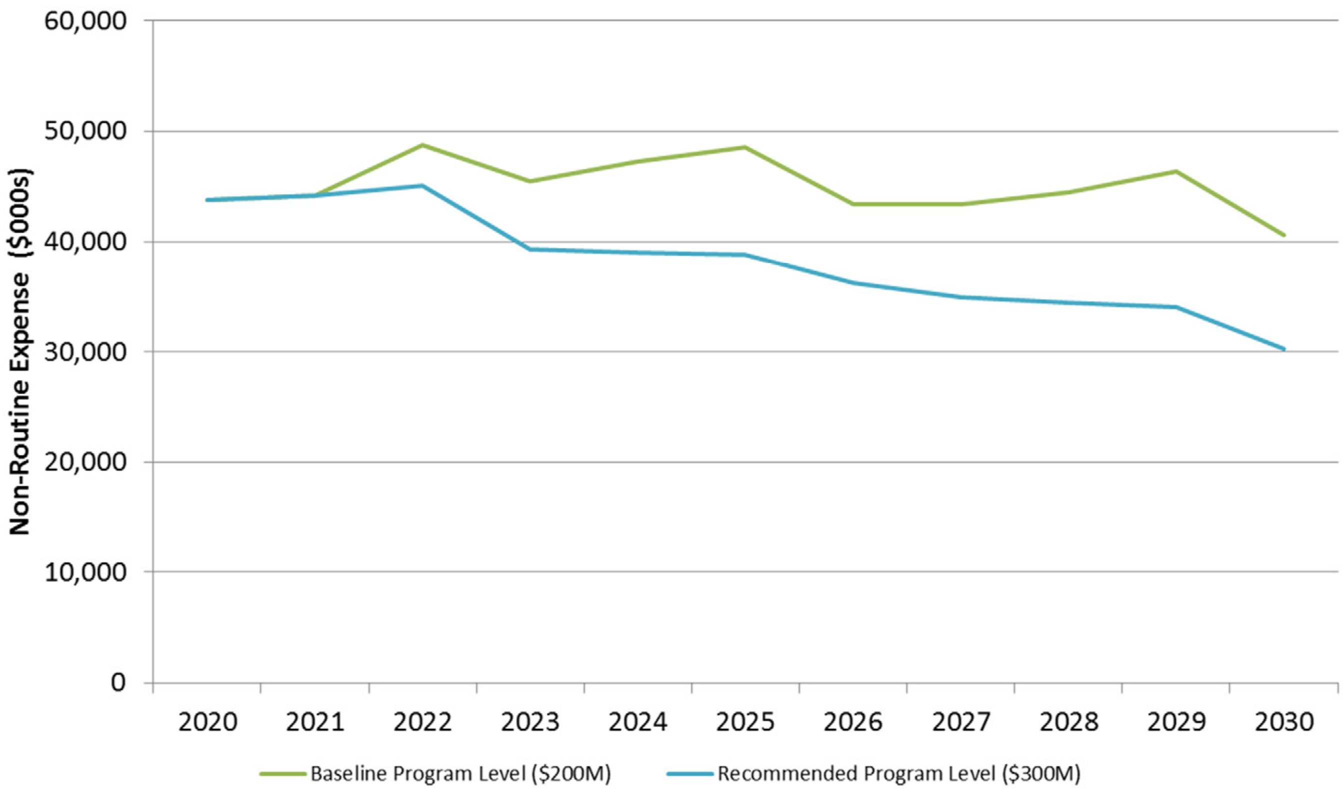
Similarly, the $300 million scenario has less than half the number of assets in the Environmental High Risk category compared to the Baseline scenario (42 vs 93).

Recommended Program Level - $300M Annual Capital Investment Level (2016 Dollars)

Lost Generation Risk by Plant in 2028



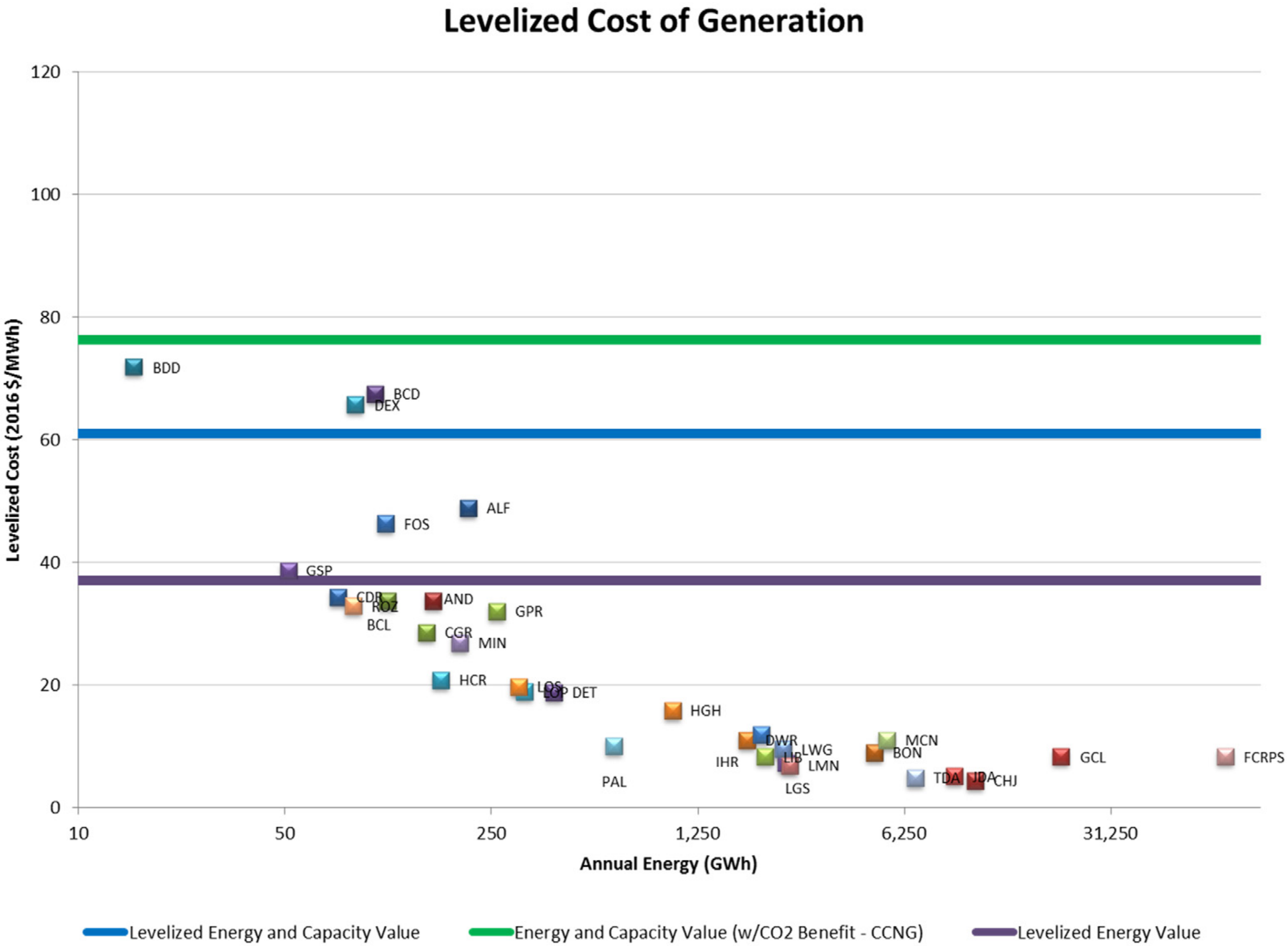
Increased, proactive investment in the hydro system reduces the risk of failures as well as reactive maintenance and replacement. Reactive work tends to manifest itself in the form of Non-Routine expense. Through Direct Cost Risk's inherent connection with reactive work, a relationship has been established between Direct Cost Risk and Non-Routine expense. Where the Baseline Program keeps Non-Routine expense flat following the completion of the Grand Coulee Third Powerplant overhauls, the recommended program level is forecast to drive it down over time. Impacts of higher program levels are not modelled to begin until 2022, when the first equipment addressed by the incremental funding are placed back in service. A correlation between Capital Investment and Routine Operations and Maintenance levels has yet to be established, but investigations into the relationship will continue for future strategies.



7. ECONOMICS AND RATE IMPACTS OF THE STRATEGY

Levelized Cost of Generation (excludes sunk costs)

- In contrast to the current cost of generation shown on page 22, the levelized incremental cost of generation includes all forecasted new capital investment and O&M expenses through 2031.
- The levelized incremental cost of generation is $8.40/MWh (2016 dollars) for the FCRPS hydro system and below $16 per MWh for all plants in the Main Stem Columbia and Headwater/Lower Snake strategic classes.
- Most other plants have levelized incremental costs below $35 per MWh.
- Forecasted levelized costs for 25 of the 31 plants are below the value of energy generated by the facility, represented by the purple line on the chart on page 104. 28 plants are below the value of energy and capacity, represented by the blue line. The levelized cost of generation for all plants is below the total value produced by the plant when energy, capacity and avoided CO_2 emissions are considered.


Levelized Cost of Generation
Levelized Cost (2016 $/MWh)
120
100
80
60
40
20
0
10
50
250
1,250
6,250
31,250
Annual Energy (GWh)
BDD
BCD
DEX
FOS
ALF
GSP
CDR
ROZ
BCL
AND
GPR
CGR
MIN
HCR
LOS
LOP
DET
HGH
PAL
IHR
DWR
LIB
LWG
LMN
LGS
MCN
BON
TDA
JDA
CHJ
GCL
FCRPS
Levelized Energy and Capacity Value
Energy and Capacity Value (w/CO2 Benefit - CCNG)
Levelized Energy Value

Long Term Rate Impact Study

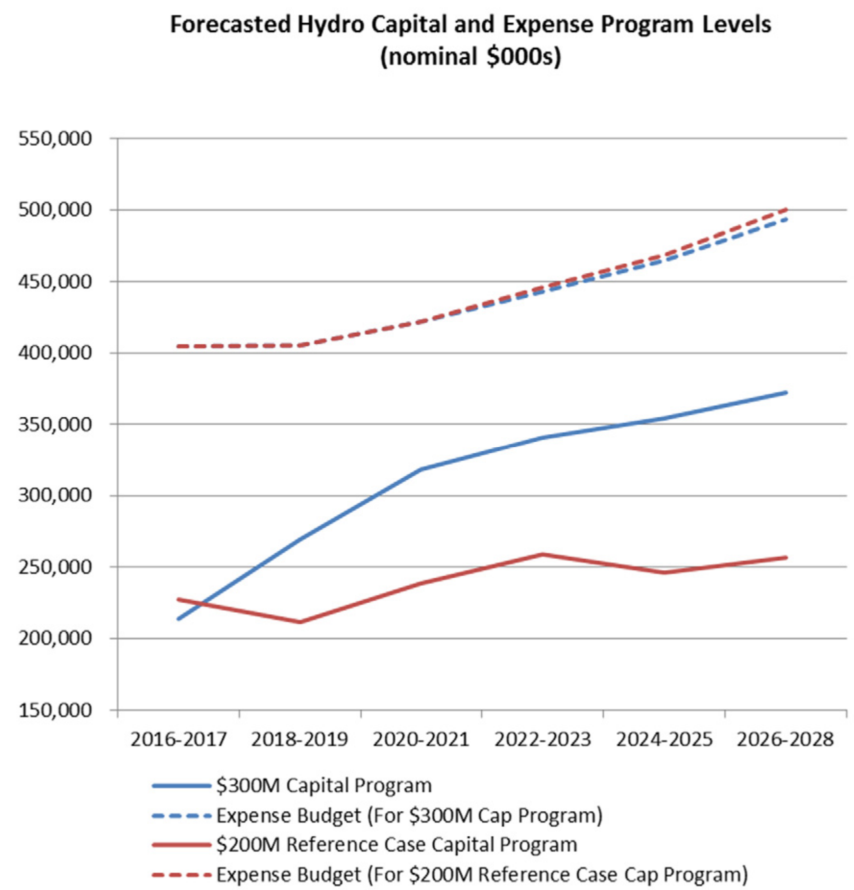
Supporting the Asset Management Key Strategic Initiative's call for a better understanding of the long-term rate impacts of alternative funding levels, BPA's Long-Term Rates Forecast screening tool was used to perform a sensitivity analysis comparing the rate impacts of the $300 million Recommended Program against the $200 million Baseline Program. This sensitivity analysis considers:

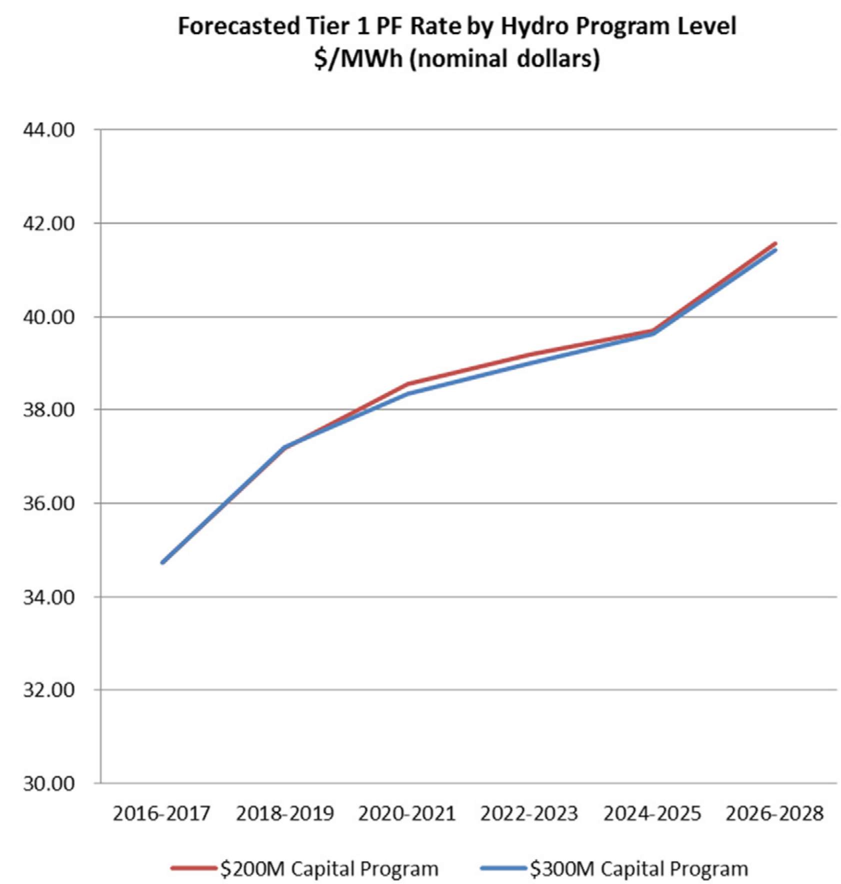
- The incremental Capital spend associated with the Recommended Program
- The resulting financing and access to Capital strategies as well as their accompanying impacts on the revenue requirement
- Monthly flow and energy price variation across an 80 year water record
- Increases or decreases in forecasted generation based on annual Lost Generation Risk forecasts that are derivative of this strategy
- Increases or Decreases in forecasted Non-Routine expense due to increased proactive replacement and less reactive maintenance

The model does not consider:

- Value of reserves, capacity, voltage regulation or other ancillary service values produced by the hydro system.

Long Term Rate Impact Study Results





Preliminary results from the study suggest that rates will be slightly lower in 2028 with the $300 million per year Recommended hydro capital program level than with the $200 million per year Baseline Program due to increased generation from higher unit availability and reduced Non-Routine expense. The largest impact is on Net Secondary Revenues as higher unit availability translates into fewer replacement power purchases and a greater opportunity for surplus sales.

The $300 million Recommended Program level has the following impacts compared to the Baseline Program:

- Reduces lost generation risk by more than 1,500 GWh per year by 2028.
- Reduces expected future Non-Routine Expense by $10 million per year by 2028 (with that difference projected to grow over time).
- Stems the declining trend in condition and replaces a majority of the powertrain assets at a more reasonable age compared to design life.
- Has little to no impact on rates through higher unit availability resulting in increased generation and less reactive maintenance. Modeling results indicate the Recommended Program would result in slightly lower rates in 2028 compared to the Baseline Program, all else equal.

Overall, the Recommended Program better positions the FCRPS to provide reliable, low-cost, environmentally sustainable power for decades to come.

8. MEASURING PERFORMANCE

The Performance Committee is a three agency subcommittee of the FCRPS Joint Operating Committee (JOC) tasked with developing, tracking, analyzing and reporting on Key Performance Indicators (KPIs). Each year, Exhibit C to Corps and Reclamation Direct Funding Agreements are modified to set the KPI's and targets that will be tied to an incentive payment for that year. For 2016 those metrics are:

- Safety (DART - Days Away, Restricted or Transferred)
- Total Expense Expenditure Rate
- Capital Budget Expenditure Rate
- Weighted Availability Factor
- Weighted Forced Outage Factor
- PM Completion Rate

Additionally, there are a series of officially tracked metrics that do not feed in to incentive payment but are studied for analysis purposes.

- Generation System Reliability (WECC/NERC Compliance)
- Base Expense Expenditure Rate
- NREX Expenditure Rate
- Small Capital Expenditure Rate
- Weighted Scheduled Outage Factor
- Safety (LTAR - Lost Time Accident Rate)
- Safety (TCIR - Total Case Incidence Rate)

In recent years, the Performance Committee has worked on the development of new metrics that better reflect the performance and maintenance of critical assets as well as the implementation of the Asset Strategy. Current key initiatives are:

Value Weighted Availability

Megawatt Weighted Availability, the industry accepted method for measuring unit availability, is not necessarily the most effective measure of performance. Setting an unnecessarily high availability target could result in plants intentionally forgoing necessary maintenance in order to meet a target, even if the units are not needed in low flow conditions. The Performance Committee has developed a Value Weighted Availability metric for the eight run-of-river plants on the Lower Columbia and Lower Snake. Instead of measuring the percentage of time a plant was available in a given period, it compares the amount of value generated by the plant against what it could have potentially generated if all units were available during a given period. Compared to a Megawatt Weighted Availability metric, the Value Weighted Availability metric should be a better measure of actual performance as it is directly related to the revenue losses associated with unavailability. Performance targets for Value Weighted Availability have not yet been set as data is still being collected and analyzed.

Critical PMs

During 2016, a team will be investigating the difference in the definition of critical assets between the plants in the FCRPS with the ultimate goal of standardization across the system. This will result in an improved maintenance performance metric focused on completion of preventive maintenance on critical assets.

Lost Generation Risk Reduction

The Performance Committee has previously proposed metrics related to measure Capital Program performance by tracking Lost Generation Risk reductions outlined in previous Hydro Asset Strategies but none have been adopted to date. Through the Asset Investment Excellence Initiative (AIEI), these types of metrics will be further evaluated and implemented through the Performance Committee over the coming years.

Performance Objectives

In a time of heavy reinvestment, high availability factors are not practical. However, near term outage coordination is highly important for marketing and river operations. The following are availability targets for each plant in the FCRPS for FY16.

Plant	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	EOY
Grand Coulee	60.65%	54.54%	58.23%	55.42%	61.53%	61.00%	67.63%	70.45%	73.18%	76.41%	76.00%	66.87%	**65.18%**
Chief Joseph	61.96%	85.79%	85.33%	86.36%	87.78%	86.89%	87.21%	90.56%	89.66%	87.80%	86.65%	69.43%	**83.77%**
John Day	82.31%	57.30%	80.38%	73.71%	76.79%	76.95%	76.21%	84.88%	85.56%	83.27%	87.70%	81.39%	**78.92%**
The Dalles	87.56%	85.12%	88.24%	88.24%	86.48%	87.68%	81.89%	80.33%	80.06%	80.57%	78.59%	82.93%	**83.98%**
Bonneville	72.44%	85.57%	87.20%	86.85%	92.48%	85.55%	85.21%	87.49%	82.75%	73.85%	88.60%	68.29%	**83.00%**
McNary	82.77%	88.68%	96.34%	87.96%	88.16%	97.01%	95.61%	96.28%	96.26%	92.22%	94.65%	93.76%	**92.49%**
Little Goose	74.17%	73.07%	74.34%	79.79%	76.62%	92.40%	94.51%	93.63%	93.58%	79.63%	65.20%	95.20%	**82.64%**
Lower Monumental	64.49%	71.21%	77.58%	81.83%	81.83%	79.15%	81.83%	81.16%	78.85%	58.45%	56.03%	64.24%	**73.00%**
Lower Granite	79.07%	82.09%	91.42%	82.68%	80.41%	78.72%	80.42%	80.44%	80.42%	67.78%	57.26%	64.27%	**77.07%**
Ice Harbor	94.24%	79.13%	82.36%	80.41%	79.71%	77.23%	78.77%	78.79%	78.50%	68.55%	58.28%	76.87%	**77.72%**
Libby	96.52%	85.91%	98.80%	80.88%	80.57%	78.80%	84.36%	98.80%	96.29%	76.08%	81.96%	83.69%	**86.91%**
Dworshak	82.29%	65.92%	90.43%	98.00%	43.36%	54.07%	98.00%	98.00%	98.00%	98.00%	98.00%	39.79%	**80.58%**
Hungry Horse	77.20%	98.10%	98.10%	65.47%	49.14%	70.95%	56.66%	62.88%	78.38%	87.03%	73.10%	79.21%	**74.79%**
Palisades	52.26%	57.93%	73.80%	73.80%	73.80%	70.81%	61.79%	83.75%	98.80%	98.80%	98.80%	98.80%	**78.61%**
Lookout Point	98.00%	98.00%	98.00%	98.00%	98.00%	98.00%	98.00%	86.35%	75.50%	84.74%	84.65%	84.30%	**91.79%**
Detroit	59.29%	98.00%	98.00%	98.00%	98.00%	98.00%	98.00%	95.24%	48.00%	52.17%	48.00%	71.13%	**80.07%**
Green Peter	98.00%	98.00%	98.00%	98.00%	98.00%	98.00%	93.42%	98.00%	98.00%	98.00%	70.72%	67.31%	**92.80%**
Lost Creek	44.89%	96.50%	96.50%	68.54%	83.28%	18.01%	0.00%	0.00%	44.28%	96.50%	96.50%	77.06%	**59.52%**
Albeni Falls	98.80%	74.68%	95.89%	98.80%	98.80%	98.80%	98.80%	98.80%	98.80%	76.53%	76.85%	73.57%	**90.76%**
Anderson Ranch	90.75%	58.71%	76.30%	99.96%	62.53%	60.18%	99.96%	99.96%	99.96%	99.96%	99.96%	99.96%	**87.46%**
Hills Creek	45.00%	45.00%	45.00%	45.00%	45.00%	47.15%	95.00%	75.11%	95.00%	95.00%	48.76%	95.00%	**64.58%**
Cougar	95.00%	95.00%	95.00%	95.00%	95.00%	68.05%	92.22%	95.00%	18.19%	44.46%	93.92%	95.00%	**81.82%**
Minidoka	48.14%	34.59%	62.79%	54.35%	45.11%	58.11%	61.36%	62.79%	62.79%	62.79%	62.79%	63.13%	**56.63%**
Big Cliff	97.00%	97.00%	97.00%	97.00%	97.00%	97.00%	7.97%	10.84%	97.00%	97.00%	97.00%	97.00%	**82.41%**
Foster	57.29%	96.00%	96.00%	96.00%	87.81%	96.00%	96.00%	96.00%	67.04%	67.71%	96.00%	91.28%	**86.92%**
Green Springs	0.72%	0.00%	0.00%	68.05%	98.70%	52.19%	98.70%	98.70%	98.70%	98.70%	98.70%	98.70%	**67.20%**
Dexter	0.00%	93.00%	93.00%	93.00%	90.70%	43.40%	67.44%	93.00%	93.00%	93.00%	93.00%	93.00%	**78.42%**
Roza	0.00%	66.04%	98.40%	98.40%	98.40%	98.40%	98.40%	98.40%	98.40%	98.40%	98.40%	46.11%	**83.08%**
Chandler	41.31%	80.78%	28.67%	98.70%	98.70%	98.70%	98.70%	98.70%	59.22%	48.70%	48.70%	48.70%	**70.63%**
Black Canyon	98.35%	66.09%	69.75%	98.35%	98.35%	98.35%	98.35%	98.35%	98.35%	98.35%	98.35%	98.35%	**93.28%**
Boise Diversion	64.31%	0.00%	0.00%	0.00%	0.00%	0.00%	96.77%	98.85%	98.85%	98.85%	98.85%	98.85%	**54.22%**
FCRPS	**72.16%**	**71.66%**	**73.62%**	**73.88%**	**74.17%**	**74.50%**	**75.08%**	**75.88%**	**76.55%**	**76.83%**	**76.99%**	**76.73%**	**76.72%**

SUMMARY

The approach in creating this 2018 Hydro Asset Strategy is consistent with that used for the previous three strategies.

The strategy identifies condition and risk implications of the currently committed hydro investment program and new investments prioritized around minimizing lifecycle cost.

The strategy includes electrical and mechanical equipment on hydropower specific and joint-use features, but excludes costs for large dam safety civil features and repairs and replacements of aging hatchery and fish passage facilities constructed for Columbia River Fish Mitigation and the Lower Snake Compensation Plan.

The strategy also excludes an evaluation of specific issues that may result in new strategic initiatives, e.g., capacity expansion opportunities, pumped storage and automation. Studies required for these issues are detailed and unique. If and when those studies develop, they will be summarized and reflected in future strategies.

BPA's Mission states that it will assure the Pacific Northwest:

- An adequate, efficient, economical and reliable power supply
- Mitigation of the Federal Columbia River Power System's impacts on fish and wildlife

BPA's vision is to be a national leader in providing:

- High reliability
- Low rates consistent with sound business principles
- Responsible environmental stewardship
- Accountability to the region

Supporting BPA's Strategic Direction, the $300 million Recommended Program in this strategy achieves these goals by identifying an investment level and investments that sustain the ability of the FCRPS to deliver clean, low cost power over the long term while having little to no forecasted impact on rates through improved reliability and availability. This program employs both industry standard and industry leading planning, prioritizing and investing practices to identify and mitigate the financial, safety and environmental risks posed to the region.

Implementation of the Hydro Asset Strategy

The Asset Investment Excellence Initiative (AIEI) was implemented at the direction of the senior executives of the Bonneville Power Administration, the Northwestern Division, U.S. Army Corps of Engineers, and the Pacific Northwest Regional Office, Bureau of Reclamation. The executives developed a Statement of Strategic Intent on February 26, 2015 that provided the primary direction for the initiative. Highlights of the statement include the intent to:

- Identify and communicate the top investment priorities including the optimization of investments and the alignment of system capabilities.
- Establishment of a long-term asset planning function to prepare rolling 20-year Asset Investment Plans for each facility in the FCRPS and an integrated 20-year FCRPS Asset Plan for the System.
- Utilization of innovative process methodologies to improve program execution. Key elements will include:
  - utilization of an asset investment methodology that effectively and economically informs investment decisions,
  - execution metrics that ensure the strategy is meeting the stated goals
- Acquisition/procurement strategies that strive to achieve cost efficiencies and minimize overhead costs.
- A multi-agency human capital plan that ensures the asset investment strategy can be implemented and executed effectively

The AIEI is well aligned with the Asset Management KSI's goals for improving investment creation, selection and execution and understanding how those investments fit into the context of the total FCRPS investment portfolio. Further information is available in the Capital Efficiency Improvement Plan attached to this strategy.

FEDERAL COLUMBIA RIVER

FCRPS

POWER SYSTEM

APPENDIX A – CAPITAL PROGRAM

Capital Program

- The capital program is managed by a 3-Agency Capital Workgroup
- The CWG meets six times per year to review and approve new investments
- Capital program managers also meet six times per year to:
  - review investments identified in the asset strategy and, from that, develop a high level plan for out years; and,
  - to do real-time management of active subagreement contracts in order to prioritize and schedule projects within the program budget.

The CWG uses staging to order projects within the program based on each project's level of maturity.

- Stage 4: mature projects that are in flight. Projects are ranked to support real-time management.
- Stage 3: mature projects that are not yet in flight, but are next in line.
- Stage 2: equipment identified in the asset strategy aggregated into first order projects. Schedules are high level and fluid.
- Stage 1: equipment identified in the asset strategy not covered in other stages.

Capital Program Planning and Implementation Criteria

Planning Criteria	Stage	Implementation Criteria					
Approved projects in flight	4	Under contract (non-deferrable)	Priority, Critical, Essential (life safety, environmental or regulatory compliance, etc) (non-deferrable)	Phase 2 approved, contract advertized but not awarded (non-deferrable)	Phase 2 approved, contract not advertized (deferrable)	Phase 1 underway (exploratory studies to refine project Phase 2 scope, cost and schedule) (deferrable)	Phase 1 approved but not yet underway (exploratory studies to refine project Phase 2 scope, cost and schedule) (deferrable)
Mature projects not yet approved	3	Refined cost and schedule estimates awaiting funding approval. Consistent with asset strategy	Developing refined cost and schedule estimates				
Equipment identified in the asset strategy aggregated into first order projects	2	Cost and schedule estimates are high level and fluid					
Equipment identified in the asset strategy not covered in other stages	1 (Asset Analytics)						

Capital Program Projects

By Plant, Stage and Start Year

Albeni Falls	ALB GDACS and Spillway	Stage 4	2004
Albeni Falls	ALB Governor (SYS Governor Repl.)	Stage 4	2002
Albeni Falls	ALB Intake Crane Modernization (Ph. 1 & Ph. 2)	Stage 4	2009
Albeni Falls	ALB Main Unit Transformers Replacement (Ph 2)	Stage 3	2019
Albeni Falls	ALB Main Unit Transformers Replacement (Phase 1)	Stage 4	2014
Albeni Falls	ALB Motor Operator Disconnects (MOD) Replacement (Phase 2)	Stage 2	2016
Albeni Falls	ALB Powerhouse Life Safety Alarm System	Stage 4	2013
Albeni Falls	ALB Spillway Crane Modernization (Ph. 1 & Ph. 2)	Stage 4	2009
Albeni Falls	ALB Spillway Gate Modifications (Ph. 1&2)	Stage 4	2012
Albeni Falls	ALB Station Service Switchgear Replacement (Phase 1)	Stage 4	2014
Albeni Falls	ALF Motor Operated Disconnects (MOD) Replacement (Phase 1)	Stage 4	2015
Anderson Ranch	AND SRA Microwave System Upgrade (Ph2)	Stage 4	2010
Anderson Ranch	AND Station Service Upgrade	Stage 4	2014
Big Cliff	BCL Digital Governor	Stage 4	2012
Big Cliff	BCL Spillway Bulkhead Gates (Joint)	Stage 4	2009
Big Cliff	BCL Spillway Tainter Gate Rehabilitation	Stage 4	2011
Big Cliff	BCL Turbine Platform (Ph 1)	Stage 4	2016
Big Cliff	BCL Turbine Platform (Ph 2)	Stage 2	2017
Big Cliff	WVY and LOS GDACS_BCL (Ph 1)	Stage 4	2015
Big Cliff	WVY and LOS GDACS_BCL (Ph 2)	Stage 2	2018
Black Canyon	BCD Install Trash Rake System (Ph1 & 2)	Stage 4	2011
Black Canyon	BCD New Unit (Ph1a & 1b)	Stage 4	2008
Black Canyon	BCD SRA Microwave System Upgrade	Stage 4	2010
Black Canyon	BCD Units 1 & 2 Upgrades (Ph1)	Stage 4	2011
Black Canyon	BCD Units 1 & 2 Upgrades (Ph2)	Stage 3	2018
Boise Diversion	BOI SRA Microwave System Upgrade	Stage 4	2010
Bonneville	BON 1 & 2 Governor Oil Filtration System	Stage 4	2012
Bonneville	BON 1 & 2 Headgates	Stage 4	2000
Bonneville	BON 1 Elevators 1 & 2 Replacement	Stage 4	2009
Bonneville	BON 1 Headgate Repair Pit Rehabilitation (Ph 1)	Stage 4	2016
Bonneville	BON 1 Headgate Repair Pit Rehabilitation (Ph 2)	Stage 2	2020
Bonneville	BON 1 Main Unit Breaker & Station Service Reconfiguration (Ph 1)	Stage 4	2010
Bonneville	BON 1 Personnel Safety Improvements (Ph 1)	Stage 4	2015
Bonneville	BON 1 Personnel Safety Improvements (Ph 2)	Stage 3	2018
Bonneville	BON 1 Rehabilitation	Stage 4	2004
Bonneville	BON 1 Tailrace Deck & Crane	Stage 4	2007
Bonneville	BON 2 Digital Governors (Mrgd)	Stage 4	2011
Bonneville	BON 2 Draft Tube Stoplogs (Ph 1)	Stage 4	2014
Bonneville	BON 2 Exciter Installation	Stage 4	2005
Bonneville	BON 2 Gantry Crane 7 Rehab.	Stage 4	2006
Bonneville	BON 2 Generator Protective Relay Replacement	Stage 4	2011
Bonneville	BON 2 Roof Replacement (Ph 1)	Stage 4	2016
Bonneville	BON 2 Roof Replacement (Ph 2)	Stage 2	2020
Bonneville	BON 2 Station Service Repl.	Stage 4	2007
Bonneville	BON 2 Tailrace Gantry Crane (Ph 1)	Stage 4	2014
Bonneville	BON 2 Tailrace Gantry Crane (Ph 2)	Stage 2	2019
Bonneville	BON 2 Transformer Improvements (Ph 1)	Stage 4	2012
Bonneville	BON Control Room Fire Protection Upgrades (Ph 1)	Stage 4	2006
Bonneville	BON Control Room Fire Protection Upgrades (Ph 2)	Stage 2	2008

Bonneville	BON GSU Instrument Transformers (Ph 1)	Stage 4	2013
Bonneville	BON Powerplant Efficiency Improvements	Stage 4	1999
Bonneville	BON Unit 11 Generator Repair	Stage 4	2013
Chandler	CDR Exciter Repl.	Stage 4	2007
Chief Joseph	CHJ 1-16 Turbine Replacement	Stage 4	2003
Chief Joseph	CHJ 480 V Distr.	Stage 4	2000
Chief Joseph	CHJ CO2 System Repl. (Phase 2)	Stage 2	2018
Chief Joseph	CHJ CO2 System Repl.(Phase I)	Stage 4	2001
Chief Joseph	CHJ DC and Preferred AC Upgrade	Stage 4	2009
Chief Joseph	CHJ Generator Cooling System Upgrades	Stage 4	2009
Chief Joseph	CHJ Governor (SYS Governor Repl.)	Stage 4	2007
Chief Joseph	CHJ Power House HVAC Upgrade	Stage 4	2017
Chief Joseph	CHJ SCC Board Replacement (Control Room) - Phase I	Stage 4	2014
Chief Joseph	CHJ SCC Board Replacement (Phase 2)	Stage 2	2016
Chief Joseph	CHJ Spillway Gate Lifecycle Maintenance	Stage 4	2015
Chief Joseph	CHJ Spilway Elevator Rehab	Stage 4	2014
Chief Joseph	CHJ Units 17-27 Exciter Repl.	Stage 4	2007
Chief Joseph	CHJ Utility Corridor (Phase 1)	Stage 4	2015
Chief Joseph	CHJ Utilty Cooridor (Phase 2)	Stage 2	2016
Cougar	COU Digital Governors	Stage 4	2012
Cougar	COU Generator Fire Protection & HVAC	Stage 4	2005
Cougar	COU Powerhouse Roof Replacement (Ph 1)	Stage 4	2015
Cougar	COU Powerhouse Roof Replacement (Ph 2)	Stage 3	2017
Cougar	COU Powerhouse Upgrade	Stage 4	2001
Cougar	COU Protective Relays Replacement	Stage 4	2009
Cougar	COU Spillway Gate Rehabilitation - 1 gate (Ph 1)	Stage 4	2015
Cougar	COU Spillway Gate Rehabilitation - 1 gate (Ph 2)	Stage 2	2018
Cougar	COU Turbine Platform (Ph 1)	Stage 4	2016
Cougar	COU Turbine Platform (Ph 2)	Stage 2	2017
Cougar	COU/HCR (COU Only) Powerhouse and Transformer Oil Water Separator	Stage 4	2009
Cougar	COU/HCR (COU Only) Powerhouse and Transformer Oil Water Separator (PH 2)	Stage 3	2010
Cougar	WVY and LOS GDACS_COU (Ph 1)	Stage 4	2013
Cougar	WVY and LOS GDACS_COU (Ph 2)	Stage 2	2018
Detroit	DET Crane Refurbishment (includes BCL)	Stage 4	2003
Detroit	DET Digital Governor	Stage 4	2012
Detroit	DET Electric Reliability Upgrades	Stage 4	2006
Detroit	DET Emergency Engine Gen. (includes BCL)	Stage 4	2007
Detroit	DET Powerhouse and Transformer Oil Water Separator (Ph 1)	Stage 4	2012
Detroit	DET Powerhouse and Transformer Oil Water Separator (Ph 2)	Stage 2	2015
Detroit	DET Remote Control (includes BCL)	Stage 4	2002
Detroit	DET Repl. Windings (includes BCL) & Oil Repl.	Stage 4	2001
Detroit	DET Spare Transformer	Stage 4	2004
Detroit	DET Spillway Gate Rehabilitation - 2 gates (Ph 1)	Stage 4	2015
Detroit	DET Spillway Gate Rehabilitation - 2 gates (Ph 2)	Stage 3	2019
Detroit	DET Turbine Platform (Ph 1)	Stage 4	2016
Detroit	DET Turbine Platform (Ph 2)	Stage 2	2017
Detroit	DET/BCL Fire Protection & HVAC	Stage 4	2009
Detroit	DET/BCL Generator Fire Protection & HVAC	Stage 4	2005
Detroit	WVY and LOS GDACS_DET (Ph 1)	Stage 4	2013
Detroit	WVY and LOS GDACS_DET (Ph 2)	Stage 2	2019

Capital Program Projects

By Plant, Stage and Start Year

Dexter	DEX Digital Governors	Stage 4	2012
Dexter	DEX Electrical Reliability Upgrades	Stage 4	2013
Dexter	DEX Headgate Refurbishment	Stage 2	2020
Dexter	DEX Powerhouse and Transformer Oil Water Separator (Ph 1)	Stage 4	2012
Dexter	DEX Powerhouse and Transformer Oil Water Separator (Ph 2)	Stage 2	2017
Dexter	DEX Spillway Bulkhead Gates (Joint)	Stage 4	2009
Dexter	DEX Spillway Tainter Gate Repair	Stage 4	2011
Dexter	WVY and LOS GDACS_DEX (Ph 1)	Stage 4	2014
Dexter	WVY and LOS GDACS_DEX (Ph 2)	Stage 2	2018
Dworshak	DWK Elevators	Stage 4	2008
Dworshak	DWK Emergency Notification (Pagers)	Stage 4	2006
Dworshak	DWK PH Bridge Cranes	Stage 4	2008
Dworshak	DWK Powerplant Efficiency Improvements	Stage 4	1999
Dworshak	DWR Digital Governor Upgrade (Phases 1 & 2)	Stage 4	2013
Dworshak	DWR Exciter Upgrade	Stage 4	2016
Dworshak	DWR Exciter Upgrade (Phase 2)	Stage 3	2018
Dworshak	DWR Powerhouse HVAC Upgrade (Phase 1 and 2)	Stage 4	2012
Dworshak	DWR Spillway Gates Repair and Load Limiting Improvements	Stage 4	2015
Dworshak	DWR Spillway Gates Repair and Load Limiting Improvements (Phase 2)	Stage 2	2018
Dworshak	DWR Unit 3 Rehabilitation - 2a Stator and Cooler	Stage 4	2013
Dworshak	DWR Upgrade RO Valve	Stage 4	2014
Dworshak	DWR Upgrade RO Valve (Phase 2)	Stage 2	2018
Dworshak	DWR Upgrade Telephone Switch and System	Stage 4	2014
Dworshak	DWR Upgrade Telephone Switch and System (Ph 2B)	Stage 3	2017
Foster	FOS Bridge Crane Rehabilitation (Ph 1)	Stage 4	2013
Foster	FOS Digital Governors	Stage 4	2011
Foster	FOS Electrical Reliability Upgrades (Ph 1)	Stage 4	2013
Foster	FOS Electrical Reliability Upgrades (Ph 2)	Stage 2	2019
Foster	FOS Powerhouse and Transformer Oil Water Separator (Ph 1)	Stage 4	2012
Foster	FOS Powerhouse and Transformer Oil Water Separator (Ph 2)	Stage 2	2019
Foster	FOS Stop Log Fabrication	Stage 4	2009
Foster	FOS Turbine Platform (Ph 1)	Stage 4	2016
Foster	FOS Turbine Platform (Ph 2)	Stage 2	2017
Foster	WVY and LOS GDACS_FOS (Ph 1)	Stage 4	2016
Foster	WVY and LOS GDACS_FOS (Ph 2)	Stage 2	2019
Grand Coulee	GCL 22-24 Spare TX & 19-21 Replacement Bank	Stage 4	1999
Grand Coulee	GCL 500 kV Switchyard Relay Replacement	Stage 4	2006
Grand Coulee	GCL 500 kV Tie to 230 kV Switchyard	Stage 4	2014
Grand Coulee	GCL CO2 Replacement	Stage 4	1999
Grand Coulee	GCL Drumgate Floating Bulkhead (Ph1)	Stage 4	2014
Grand Coulee	GCL Drumgate Floating Bulkhead (Ph2)	Stage 3	2019
Grand Coulee	GCL Elevator Rehabilitation (Ph1 & 2)	Stage 4	2009
Grand Coulee	GCL Fixed Wheel Gate Chamber Modification (Ph1 & 2)	Stage 4	2009
Grand Coulee	GCL G1-18 Runner Replacement	Stage 4	1996
Grand Coulee	GCL G1-18 Stator, Winding, Core & Spare	Stage 4	2002
Grand Coulee	GCL G11-G18 Transformer Replacement (Ph1 & 2)	Stage 4	2013
Grand Coulee	GCL G1-9 Unit Transformer Replacement	Stage 4	2008
Grand Coulee	GCL G19-20 236 MVA Transf. Repl. (6 tanks)	Stage 4	2007
Grand Coulee	GCL G19-20 Unit Uprate (winding)	Stage 4	2010
Grand Coulee	GCL G19-24 Exciter Replacement	Stage 4	2007

Grand Coulee	GCL G19-24 Governor Replacement	Stage 4	2008
Grand Coulee	GCL G19-G21 Modernization and Unit Uprate (Ph1)	Stage 4	2015
Grand Coulee	GCL G19-G21 Modernization and Unit Uprate (Ph2)	Stage 2	2016
Grand Coulee	GCL G1-G18 Governor Replacement (Ph 1 & 2)	Stage 4	2015
Grand Coulee	GCL G1-G18 Isophase Bus (Ph1)	Stage 4	2015
Grand Coulee	GCL G1-G18 Penstock Stoplogs (Ph1)	Stage 4	2016
Grand Coulee	GCL G1-G18 Static Exciter Replacement (Ph1 & 2)	Stage 4	2015
Grand Coulee	GCL G1-G18 Stator Windings, Cores and Spare Replacement Program (Ph1 & 2)	Stage 4	2015
Grand Coulee	GCL G22-G23 Wicket Gate Replacements (Ph1 & 2)	Stage 4	2015
Grand Coulee	GCL G22-G24 Wear Ring Replacement	Stage 4	2011
Grand Coulee	GCL Inclined Elevator (Ph1)	Stage 4	2015
Grand Coulee	GCL Inclined Elevator (Ph2)	Stage 3	2019
Grand Coulee	GCL Laser Light Show Replacement (Ph 1 & 2)	Stage 4	2011
Grand Coulee	GCL Left/Right Roof Replacement	Stage 4	2007
Grand Coulee	GCL LPH/RPH Crane Control Upgrades (Ph1)	Stage 4	2015
Grand Coulee	GCL LPH/RPH Crane Control Upgrades (Ph2)	Stage 2	2016
Grand Coulee	GCL Material Storage Building	Stage 4	2009
Grand Coulee	GCL New Firehouse (Ph1)	Stage 4	2015
Grand Coulee	GCL Powerplant Battery Replacement	Stage 4	2014
Grand Coulee	GCL Powerplant Efficiency Improvements	Stage 4	2001
Grand Coulee	GCL SCADA Replacement (Ph1 & 2)	Stage 4	2004
Grand Coulee	GCL Station Service Compressed Air System Upgrades (Ph1)	Stage 4	2013
Grand Coulee	GCL TPP Crane Control Upgrades - Part 2 (Ph1)	Stage 4	2015
Grand Coulee	GCL TPP Crane Control Upgrades - Part 2 (Ph2)	Stage 2	2016
Grand Coulee	GCL TPP Crane Rehabilitation	Stage 4	2009
Grand Coulee	GCL TPP High Voltage Cable Repl.	Stage 4	2009
Grand Coulee	GCL TPP K21A-K24A Transformer Replacement (Ph2)	Stage 3	2018
Grand Coulee	GCL TPP K21-K24 Transformer Replacement (Ph1)	Stage 4	2015
Grand Coulee	GCL TPP Roof Replacement - Part 2 (Ph2)	Stage 2	2019
Grand Coulee	GCL TPP Roof Rehabilitation	Stage 4	2006
Grand Coulee	GCL TPP Roof Replacement - Part 2 (Ph1)	Stage 4	2015
Grand Coulee	GCL Warehouse 3 Replacement (Ph1)	Stage 4	2015
Grand Coulee	GCL XRS Switchgear Replacement	Stage 4	2007
Green Peter	GPR Digital Governors	Stage 4	2011
Green Peter	GPR Main Unit Breakers and Electrical Reliability Upgrades (Ph 1)	Stage 4	2013
Green Peter	GPR Main Unit Breakers and Electrical Reliability Upgrades (Ph 2)	Stage 3	2019
Green Peter	GPR Powerhouse and Transformer Oil Water Separator (Ph 1)	Stage 4	2012
Green Peter	GPR Powerhouse and Transformer Oil Water Separator (Ph 2)	Stage 2	2020
Green Peter	GPR Powerhouse Bridge Crane (Ph 1)	Stage 4	2015
Green Peter	GPR Powerhouse Bridge Crane (Ph 2)	Stage 2	2018
Green Peter	GPR Spillway Gate Rehabilitation - 2 gates	Stage 4	2012
Green Peter	GPR Turbine Platform (Ph 1)	Stage 4	2016
Green Peter	GPR Turbine Platform (Ph 2)	Stage 2	2017
Green Peter	GPR/FOS Generator Fire Protection & HVAC	Stage 4	2005
Green Peter	GPR/FOS Protective Relays Replacement	Stage 4	2009
Green Peter	WVY and LOS GDACS_GPR (Ph 1)	Stage 4	2013
Green Peter	WVY and LOS GDACS_GPR (Ph 2)	Stage 2	2019
Green Springs	GSP Excitation System Replacement	Stage 4	2012
Green Springs	GSP Transformer Repl.	Stage 4	2003
Hills Creek	COU/HCR (HCR Only) Powerhouse and Transformer Oil Water Separator (Ph 2 additional wor	Stage 3	2012

Capital Program Projects

By Plant, Stage and Start Year

Hills Creek	COU/HCR (HCR Only) Powerhouse and Transformer Oil Water Separator (Ph 1)	Stage 4	2010
Hills Creek	HCR Bridge Crane Rehab.	Stage 4	2008
Hills Creek	HCR Digital Governor	Stage 4	2011
Hills Creek	HCR Generator Fire Protection & HVAC	Stage 4	2005
Hills Creek	HCR Protective Relays Replacement	Stage 4	2009
Hills Creek	HCR Spillway Gate Rehabilitation - 1 gate (Ph 1)	Stage 4	2014
Hills Creek	HCR Turbine Runner and Generator Rewind	Stage 4	2006
Hills Creek	WVY and LOS GDACS_HCR (Ph 1)	Stage 4	2013
Hills Creek	WVY and LOS GDACS_HCR (Ph 2)	Stage 2	2018
Hungry Horse	HGH CO2 Replacement	Stage 4	1999
Hungry Horse	HGH Fiber	Stage 4	2000
Hungry Horse	HGH G1-G4 Governor Replacement (Ph1)	Stage 4	2014
Hungry Horse	HGH Main Transformer Fire Protection System Replacement (Ph1)	Stage 4	2011
Hungry Horse	HGH Powerplant Crane Controls (Ph1)	Stage 4	2013
Hungry Horse	HGH Powerplant Crane Controls (Ph2)	Stage 3	2018
Hungry Horse	HGH Powerplant Windows (Ph1)	Stage 4	2015
Hungry Horse	HGH Powerplant Windows (Ph2)	Stage 4	2017
Hungry Horse	HGH SCADA Replacement (Ph1 & 2)	Stage 4	2004
Hungry Horse	HGH SS and MCC Upgrades (Ph1 & 2)	Stage 4	2011
Hungry Horse	HGH Static Exciters (Ph1)	Stage 4	2014
Ice Harbor	IHR DC System Upgrade (Ph. 1 & 2)	Stage 4	2011
Ice Harbor	IHR Draft Tube & Scroll Case Access Tugger	Stage 4	2013
Ice Harbor	IHR Drainage & De-Watering Pump Upgrade (Phase 1 and Phase 2)	Stage 4	2012
Ice Harbor	IHR Drainage System Oil Water Separator	Stage 4	2015
Ice Harbor	IHR Drainage System Oil Water Separator (Phase 2)	Stage 3	2019
Ice Harbor	IHR Emergency Notification (Pagers)	Stage 4	2006
Ice Harbor	IHR Low Voltage Switchgear Upgrades - SQ Boards (Ph. 1 & 2)	Stage 4	2011
Ice Harbor	IHR Main Units 1-6 Digital Governor (Phase 1 & 2)	Stage 4	2012
Ice Harbor	IHR MU Cooling Water Strainers Replacement	Stage 4	2015
Ice Harbor	IHR MU Cooling Water Strainers Replacement (Phase 2)	Stage 3	2017
Ice Harbor	IHR Powerplant Efficiency Improvements	Stage 4	1999
Ice Harbor	IHR Rehabilitate Non-Overflow Elevator	Stage 4	2014
Ice Harbor	IHR T1,T2,T3 Cooler Leak Repair (Phases 1 & 2)	Stage 4	2012
Ice Harbor	IHR T6 Transformer Replacement	Stage 4	2009
Ice Harbor	IHR Third Set Tailrace Stoplogs	Stage 4	2015
Ice Harbor	IHR Turbine Runner Design & Repl. Units 1,2,3	Stage 4	2001
Ice Harbor	IHR Units 1-3 Stator Winding Replacement	Stage 4	2015
Ice Harbor	IHR Units 1-3 Stator Winding Replacement (Phase 2)	Stage 3	2016
Ice Harbor	IHR Upgrade Telephone Switch and System	Stage 4	2014
Ice Harbor	IHR XJ0 SS Breaker Replacement	Stage 4	2015
Ice Harbor	IHR XJ0 SS Breaker Replacement (Phase 2)	Stage 2	2017
Ice Harbor	IHR XW-5 Breaker Repair (Phase 1 & 2)	Stage 4	2013
John Day	JDA 500Kv Disconnect Replacement (Ph 1)	Stage 4	2014
John Day	JDA 500Kv Disconnect Replacement (Ph 2)	Stage 3	2016
John Day	JDA BLH Hub Upgrade Kits	Stage 4	2013
John Day	JDA BLH Turbine Hub Upgrades and Fixed Blade Conversions (Ph 1)	Stage 4	2013
John Day	JDA Bridge Crane Rehab	Stage 4	2006
John Day	JDA Control Room Fire Protection Upgrades	Stage 4	2006
John Day	JDA DC System Upgrades (Ph 1)	Stage 4	2012
John Day	JDA Digital Governors	Stage 4	2011

John Day	JDA Draft Tube Bulkheads and Intake Gates (Ph 1)	Stage 4	2014
John Day	JDA Elevator Rehabilitation (Mrgd)	Stage 4	2010
John Day	JDA Fish Hydro Pump Rehabilitation	Stage 4	2011
John Day	JDA HVAC System Upgrade (Ph 1)	Stage 4	2016
John Day	JDA HVAC System Upgrade (Ph 2)	Stage 2	2019
John Day	JDA Oil Replacement	Stage 4	2013
John Day	JDA Powerhouse Office Space	Stage 4	2014
John Day	JDA Powerhouse Unit 11 and Unit 5 Repair	Stage 4	2011
John Day	JDA Powerplant Efficiency Improvements	Stage 4	1999
John Day	JDA Protective Relays Replacement	Stage 4	2009
John Day	JDA Rotor Pedestal (Ph 1)	Stage 4	2015
John Day	JDA SQ Board Replacement SQ1-SQ4, SQ01, SQ02 (Ph 1)	Stage 4	2015
John Day	JDA SQ Board Replacement SQ1-SQ4, SQ01, SQ02 (Ph 2)	Stage 2	2019
John Day	JDA SS Transformer Replacements (Ph 1)	Stage 4	2013
John Day	JDA Trash Rake	Stage 2	2019
John Keys PGP	GCL KP10B Transformer Replacement (Ph1)	Stage 4	2012
John Keys PGP	GCL P1-P6 Exciters, Relays & Controls, PG7-PG12 Governors, Exciters, Relays & Controls (Ph2	Stage 4	2015
John Keys PGP	GCL P5 and P6 Impellers, Stators and Core Rewinds (Ph1 & 2))	Stage 4	2012
John Keys PGP	GCL PG Plant Modernization and Upgrades	Stage 4	2010
John Keys PGP	GCL PG Transformer Repl. & Circuit Addition	Stage 4	2000
John Keys PGP	GCL PG7-PG12 Replace Unit Circuit Breakers (Ph2)	Stage 4	2014
John Keys PGP	GCL Phase Reversal Switch - High Side (in Yard)(Ph2)	Stage 4	2014
Libby	LIB Dam Electrical Distribution Equipment	Stage 4	2013
Libby	LIB GDACS and Spillway	Stage 4	2004
Libby	LIB Governor (SYS Governor Repl.)	Stage 4	2007
Libby	LIB Powerhouse Cranes	Stage 4	1999
Libby	LIB Powerhouse DC Emergency Lighting System	Stage 4	2014
Libby	LIB Powerhouse Electrical Distribution Equipment Replacement	Stage 4	2013
Libby	LIB Powerhouse Roof Replacement	Stage 4	2014
Libby	LIB System Control Console - Plant (SCC)	Stage 4	2014
Libby	LIB Water Mist - Oil Room	Stage 4	2014
Little Goose	LGS 1-6 Exciter Replacement	Stage 4	2009
Little Goose	LGS DC System and LV Switchgear Upgrade	Stage 4	2015
Little Goose	LGS DC System and LV Switchgear Upgrade (PH 2)	Stage 3	2020
Little Goose	LGS Diesel Generator	Stage 4	2007
Little Goose	LGS Digital Govenors Upgrade (Phases 1 & 2)	Stage 4	2013
Little Goose	LGS Drainage and Unwatering Pump Replacement	Stage 4	2015
Little Goose	LGS Drainage and Unwatering Pump Replacement (Ph 2)	Stage 3	2018
Little Goose	LGS Drainage System Oil Water Separator	Stage 4	2015
Little Goose	LGS Drainage System Oil Water Separator (Phase 2)	Stage 2	2019
Little Goose	LGS Emergency Notification (Pagers)	Stage 4	2006
Little Goose	LGS Intake Crane Replacement (Ph1 & Ph 2)	Stage 4	2011
Little Goose	LGS Iso Phase Bus & Housing Upgrade	Stage 4	2015
Little Goose	LGS Iso Phase Bus & Housing Upgrade (Phase 2)	Stage 3	2017
Little Goose	LGS Powerhouse Bridge Crane Rehab (Phase 1 and 2)	Stage 4	2011
Little Goose	LGS Powerplant Efficiency Improvements	Stage 4	1999
Little Goose	LGS Spare Main Unit Bearing	Stage 4	2015
Little Goose	LGS Spare Tailrace Stoplogs	Stage 4	2015
Little Goose	LGS Station Service Transformers Replacement Ph1	Stage 4	2015
Little Goose	LGS Station Service Transformers Replacement Ph2	Stage 3	2018

Capital Program Projects

By Plant, Stage and Start Year

Little Goose	LGS Upgrade Telephone Switch and System	Stage 4	2014
Little Goose	LGS Upgrade Telephone Switch and System (Ph 2B)	Stage 3	2018
Little Goose	LGS XJ01, XJ02, XJ7 Breaker Replacement	Stage 4	2015
Little Goose	LGS XJ01, XJ02, XJ7 Replacement (Phase 2)	Stage 2	2017
Lookout Point	LOP Cranes (was WVL assessment)	Stage 4	2005
Lookout Point	LOP Digital Governors	Stage 4	2013
Lookout Point	LOP Emergency Engine Generator (Mrgd)	Stage 4	2011
Lookout Point	LOP Generator Fire Protection & HVAC	Stage 4	2005
Lookout Point	LOP Penstock Roller Gates	Stage 4	2008
Lookout Point	LOP Powerhouse and Transformer Oil Water Separator (Ph 1)	Stage 4	2012
Lookout Point	LOP Powerhouse and Transformer Oil Water Separator (Ph 2)	Stage 2	2017
Lookout Point	LOP Spillway Gate Rehabilitation -- 2 gates plus	Stage 4	2013
Lookout Point	LOP Turbine Runner Replacement	Stage 4	2005
Lookout Point	LOP/DEX Protective Relays Replacement	Stage 4	2009
Lookout Point	WVY and LOS GDACS_LOP (Ph 1)	Stage 4	2013
Lookout Point	WVY and LOS GDACS_LOP (Ph 2)	Stage 2	2021
Lost Creek	LOS Butterfly Valves Replacement (Mrgd)	Stage 4	2013
Lost Creek	LOS Digital Governors	Stage 4	2011
Lost Creek	LOS Fire Protection (Ph 1)	Stage 4	2009
Lost Creek	LOS Fire Protection (Ph 2)	Stage 2	2019
Lost Creek	LOS Wicket Gate Seals Redesign/Upgrade (Ph 1)	Stage 4	2013
Lost Creek	WVY and LOS GDACS_LOS (Ph 1)	Stage 4	2013
Lost Creek	WVY and LOS GDACS_LOS (Ph 2)	Stage 2	2022
Lower Granite	LGR -- SNK Spare Winding for units 4-6 (SYS Gen)	Stage 4	2002
Lower Granite	LGR Elevator Rehab.-CNO&NNO	Stage 4	2009
Lower Granite	LGR Powerplant Efficiency Improvements	Stage 4	1999
Lower Granite	LGR Replacement Windings 1-3 (SYS Gen)	Stage 4	2001
Lower Granite	LGR SQ2 Replacement	Stage 4	2009
Lower Granite	LWG 4-6 Exciter Replacement	Stage 4	2009
Lower Granite	LWG DC System and LV Switchgear Upgrade	Stage 4	2016
Lower Granite	LWG DC System and LV Switchgear Upgrade (Ph 2)	Stage 3	2021
Lower Granite	LWG Diesel Generator	Stage 4	2007
Lower Granite	LWG Digital Governor Upgrade (Phases 1 & 2)	Stage 4	2013
Lower Granite	LWG Emergency Notification (Pagers)	Stage 4	2006
Lower Granite	LWG ISO Phase Bus & Housing Upgrade	Stage 4	2015
Lower Granite	LWG ISO Phase Bus & Housing Upgrade (Phase 2)	Stage 3	2017
Lower Granite	LWG Powerhouse Bridge Crane Rehab (Phase 1 and 2)	Stage 4	2011
Lower Granite	LWG Powerhouse HVAC Upgrade	Stage 4	2012
Lower Granite	LWG Powerhouse Roof Repair (Phase 1 & 2)	Stage 4	2013
Lower Granite	LWG Sewage Treatment Plant Upgrade	Stage 4	2011
Lower Granite	LWG Spare Main Unit Bearing	Stage 4	2015
Lower Granite	LWG U1 BLH Linkage Upgrade	Stage 4	2014
Lower Granite	LWG Upgrade Telephone Switch and System	Stage 4	2014
Lower Granite	LWG XJ01, XJ02, XJ03 SS Breaker Replacement	Stage 4	2015
Lower Granite	LWG XJ01, XJ02, XJ03 SS Breaker Replacement (Phase 2)	Stage 2	2017
Lower Monumental	LMN 4-6 Exciter Replacement	Stage 4	2009
Lower Monumental	LMN Bridge Crane Drive Upgrades	Stage 4	2013
Lower Monumental	LMN DC System and LV Switchgear Upgrade	Stage 4	2015
Lower Monumental	LMN DC System and LV Switchgear Upgrade (Ph 2)	Stage 3	2018
Lower Monumental	LMN Diesel Generator	Stage 4	2007

Lower Monumental	LMN Digital Governor Upgrade (Phases 1 & 2)	Stage 4	2013
Lower Monumental	LMN Drainage and Unwatering Pump Replacement	Stage 4	2015
Lower Monumental	LMN Drainage and Unwatering Pump Replacement (Ph 2)	Stage 3	2018
Lower Monumental	LMN Drainage System Oil Water Separator	Stage 4	2015
Lower Monumental	LMN Drainage System Oil Water Separator (Phase 2)	Stage 2	2016
Lower Monumental	LMN Emergency Notification (Pagers)	Stage 4	2006
Lower Monumental	LMN Exciters 1-3	Stage 4	2002
Lower Monumental	LMN ISO Phase Bus & Housing Upgrade	Stage 4	2015
Lower Monumental	LMN ISO Phase Bus & Housing Upgrade (Phase 2)	Stage 3	2017
Lower Monumental	LMN Powerplant Efficiency Improvements	Stage 4	1999
Lower Monumental	LMN Spare Main Unit Bearing	Stage 4	2015
Lower Monumental	LMN Spare Main Unit Bearing (Phase 2)	Stage 3	2016
Lower Monumental	LMN SQ2 Replacement	Stage 4	2009
Lower Monumental	LMN U1 Refurb, U1 and U2 Cavitation Work	Stage 4	2009
Lower Monumental	LMN Upgrade Telephone Switch and System	Stage 4	2014
Lower Monumental	LMN XJ01, XJ02 SS Breaker Replace (Phase 2)	Stage 2	2017
Lower Monumental	LMN XJ01, XJ02 SS Breaker Replacement	Stage 4	2015
McNary	MCN 230 KV Transformer Purchase	Stage 4	2014
McNary	MCN 4160-480V Station Service Replacement	Stage 4	2010
McNary	MCN Bridge Crane Fall Protection System	Stage 4	2012
McNary	MCN Digital Governors U1-14 (Phase 1 & 2)	Stage 4	2013
McNary	MCN Exciters Upgrade	Stage 4	2014
McNary	MCN Exciters Upgrade (Phase 2)	Stage 3	2018
McNary	MCN Fire Protection	Stage 4	2006
McNary	MCN Fishway Exit Crane 9 and 10 Replacement (Ph. 1 & 2)	Stage 4	2011
McNary	MCN Fourth Spare Tailrace Bulkheads	Stage 4	2014
McNary	MCN Generator Rewinds	Stage 4	2008
McNary	MCN Levee Drainage Pump Station Upgrades (Ph. 1)	Stage 4	2011
McNary	MCN Levee Drainage Pump Station Upgrades (Ph. 2)	Stage 3	2019
McNary	MCN MU Cooling Water Strainers Replacement	Stage 4	2015
McNary	MCN MU Cooling Water Strainers Replacement (Phase 2)	Stage 3	2016
McNary	MCN PH Bridge Cranes - Skew Control	Stage 4	2015
McNary	MCN PH Heat Pump & Control Replacement (Ph. 1 and 2)	Stage 4	2011
McNary	MCN Potable Water System Upgrade	Stage 4	2011
McNary	MCN Powerplant Efficiency Improvements	Stage 4	1999
McNary	MCN Project Storage Building	Stage 4	2014
McNary	MCN Rehab Spillway Gates and Gate Hoists Uprate	Stage 4	2015
McNary	MCN Rehab Spillway Gates and Gate Hoists Uprate (Phase 2)	Stage 2	2019
McNary	MCN Reliability Improvement (except turbine)	Stage 4	2002
McNary	MCN Roof Replacement	Stage 4	2006
McNary	MCN Spare Main Unit Bearing	Stage 4	2016
McNary	MCN Transformer Purchase	Stage 4	2008
McNary	MCN Turbine Design and Replacement (Phase 1)	Stage 4	2011
McNary	MCN Turbine Design and Replacement (Phase 2)	Stage 3	2018
McNary	MCN Turbine Runner Accessories	Stage 4	2002
McNary	MCN Turbine Runner Replacement	Stage 4	2002
McNary	MCN U14 Upper Bearing Bracket Crack Repair (Phase 1 & 2)	Stage 4	2013
McNary	MCN Upgrade Precipitron	Stage 4	2015
McNary	MCN Upgrade Telephone Switch and System	Stage 4	2014
McNary	MCN Upgrade Telephone Switch and System (Ph 2B)	Stage 3	2018

Capital Program Projects

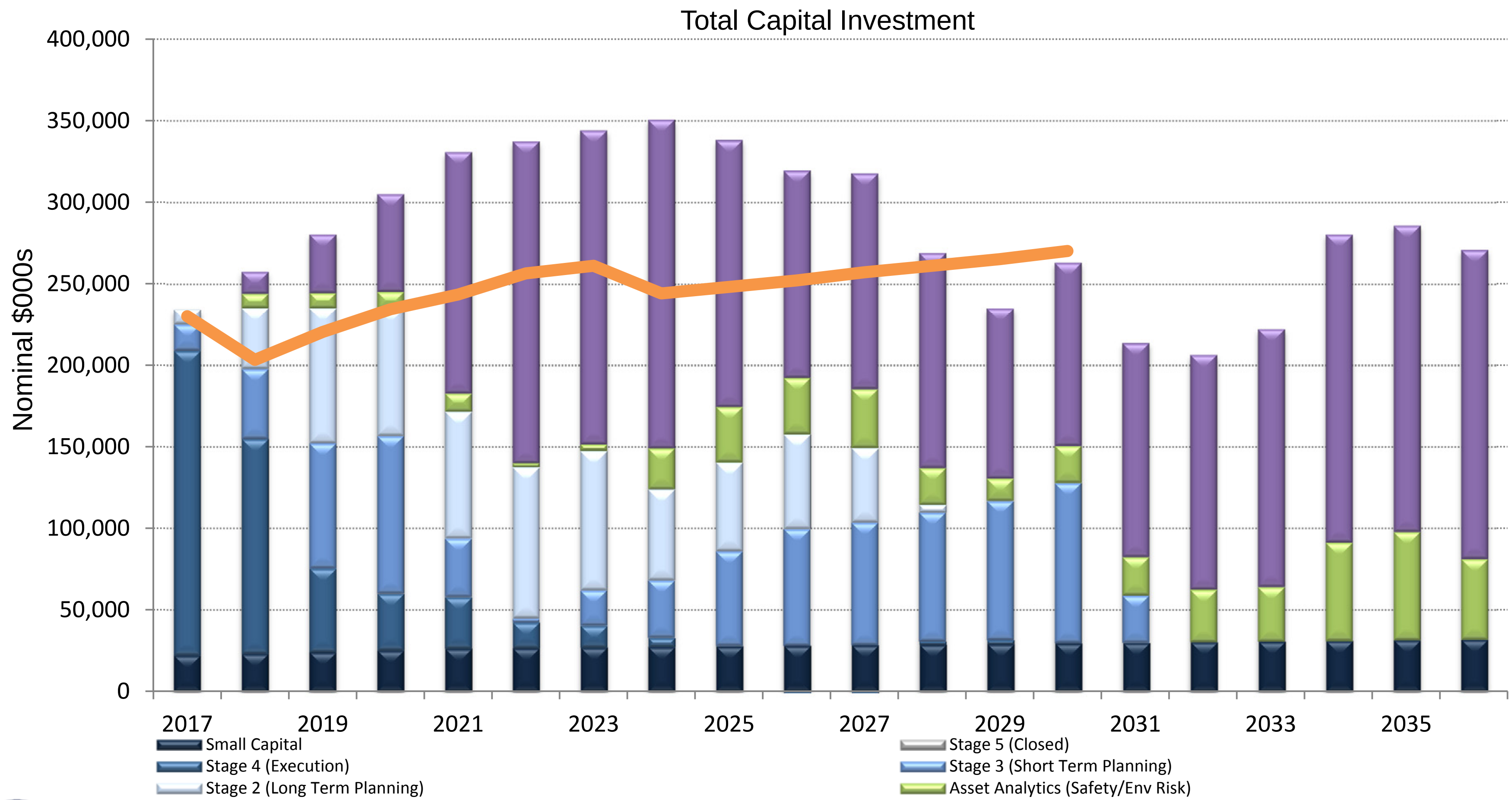
By Plant, Stage and Start Year

McNary	MCN WAFL Entrance Logs (Phase 1)	Stage 4	2011
Minidoka	MIN Arc Flash Mitigation (Ph 2)	Stage 4	2015
Minidoka	MIN Inman Units 8 & 9 - Replace Governor System (Ph1 & 2)	Stage 4	2014
Minidoka	MIN Microwave System Backbone East Side (Ph1 & 2)	Stage 4	2014
Minidoka	MIN SRA Microwave System Upgrade	Stage 4	2010
Minidoka	MIN Switchyard Modernization (Ph1)	Stage 4	2015
Minidoka	MIN Switchyard Modernization (Ph2)	Stage 3	2018
Minidoka	MIN/PAL Modifications	Stage 4	2000
Palisades	PAL Arc Flash Mitigation (Ph2)	Stage 4	2015
Palisades	PAL Microwave System Backbone East Side (Ph1 & 2)	Stage 4	2014
Palisades	PAL Powerplant Efficiency Improvements	Stage 4	2002
Palisades	PAL Powerplant Fire Detection and Alarm System	Stage 4	2012
Palisades	PAL SRA Microwave System Upgrade	Stage 4	2010
Palisades	PAL Switchyard Modernization (Ph1)	Stage 4	2015
Palisades	PAL Switchyard Modernization (Ph2)	Stage 3	2017
Palisades	PAL Turbine Runner Replacement	Stage 4	2009
Roza	ROZ Exciter Repl.	Stage 4	2007
Roza	ROZ Switch Rehab and Breaker Upgrade	Stage 4	2014
The Dalles	TDA Arc Flash Hazard Reduction (Ph 1)	Stage 4	2015
The Dalles	TDA Arc Flash Hazard Reduction (Ph 2)	Stage 3	2018
The Dalles	TDA Bay 15 Elevator Rehabilitation	Stage 4	2015
The Dalles	TDA Control Room Fire Detection Upgrades	Stage 4	2005
The Dalles	TDA DC System Upgrades	Stage 4	2011
The Dalles	TDA Elevator Rehabilitation (Mrgd)	Stage 4	2010
The Dalles	TDA Fish Unit Breaker Replacement (Ph 1)	Stage 4	2014
The Dalles	TDA Fish Unit Breaker Replacement (Ph 2)	Stage 2	2018
The Dalles	TDA Gate Repair Pit Upgrades (Ph 1)	Stage 4	2015
The Dalles	TDA Gate Repair Pit Upgrades (Ph 2)	Stage 2	2017
The Dalles	TDA Governor (SYS Governor Repl.)	Stage 4	2001
The Dalles	TDA Heat Pump #3 & Coil Replacement	Stage 4	2006
The Dalles	TDA Oil/Water Separator (SYS)	Stage 4	2003
The Dalles	TDA Powerhouse Roof Replacement	Stage 4	2010
The Dalles	TDA Powerplant Efficiency Improvements	Stage 4	1999
The Dalles	TDA Preferred AC System Upgrades	Stage 4	2013
The Dalles	TDA SCC Control Replacement (Ph 1)	Stage 4	2012
The Dalles	TDA Spare 230 KV Transformer Repl.	Stage 4	2005
The Dalles	TDA Spillway Repair	Stage 4	2006
The Dalles	TDA SR Panel Replacement (Ph 1)	Stage 4	2015
The Dalles	TDA SR Panel Replacement (Ph 2)	Stage 3	2018
The Dalles	TDA Station Service Improvement	Stage 4	2004
The Dalles	TDA Synchr. Cond. Upgrade (funded by TBL)	Stage 4	2004
The Dalles	TDA Tailrace Gantry Crane (Ph 1)	Stage 4	2012
The Dalles	TDA Transformer Replacement TA,1,3,5,6,7,8 (Ph 1)	Stage 4	2013

APPENDIX B – SENSITIVITY ANALYSES

Low Long Term Energy Prices – 8% Discount Rate

The impacts of prolonged low energy prices were also studied to determine the impacts on suggested capital investment levels. Assuming a $20 real levelized energy price, no value for capacity or ancillary services, no value for avoided carbon emissions and an 8% discount rate, the analytics still suggest that it is optimal to spend approximately $300 million through the mid 2020s. This program has a Net Present Value of $121 million relative to the baseline program.

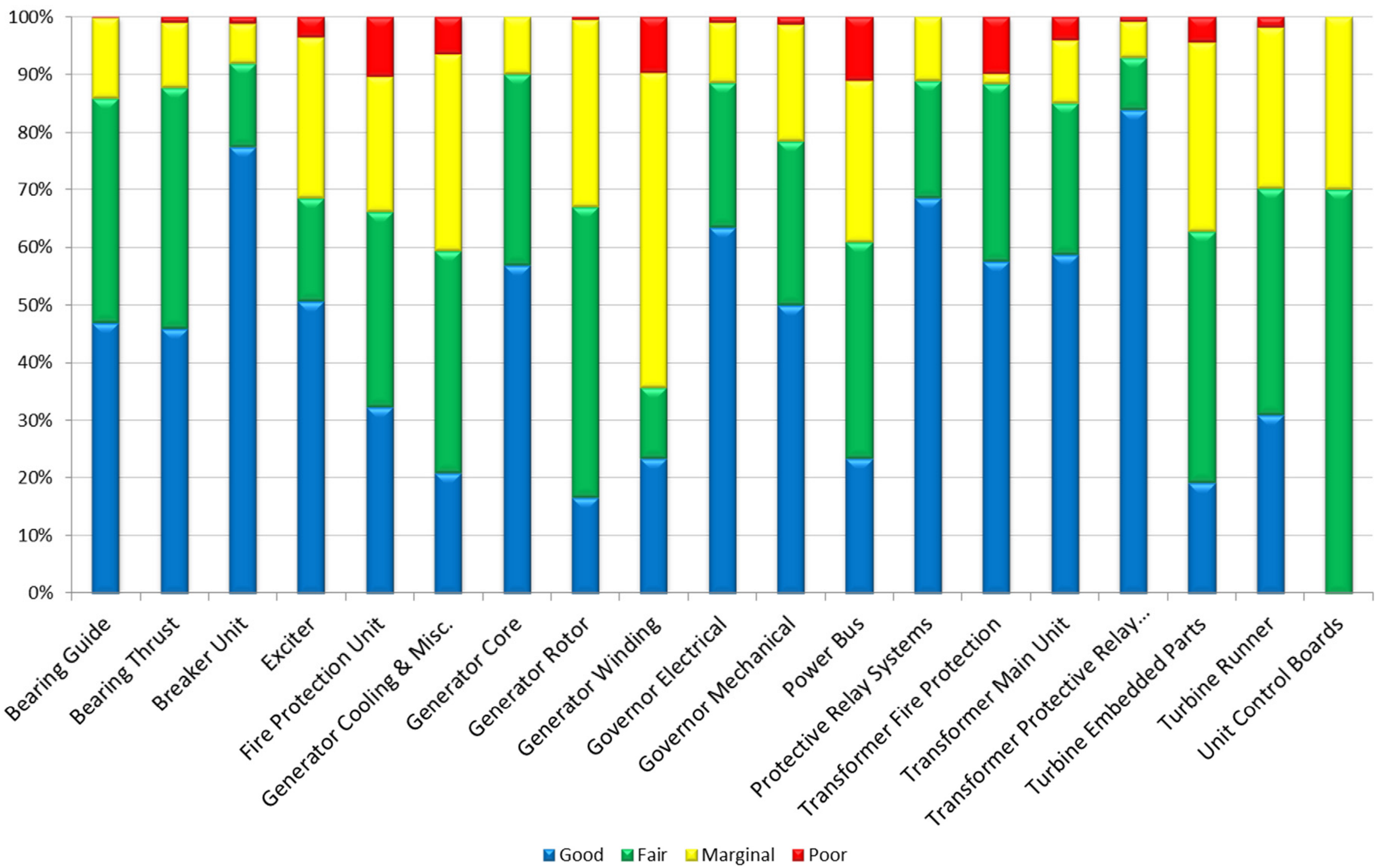


The following table presents the Net Present Values of Capital Investment relative to the baseline program for a set of energy price, discount rate and CO2 sensitivities.

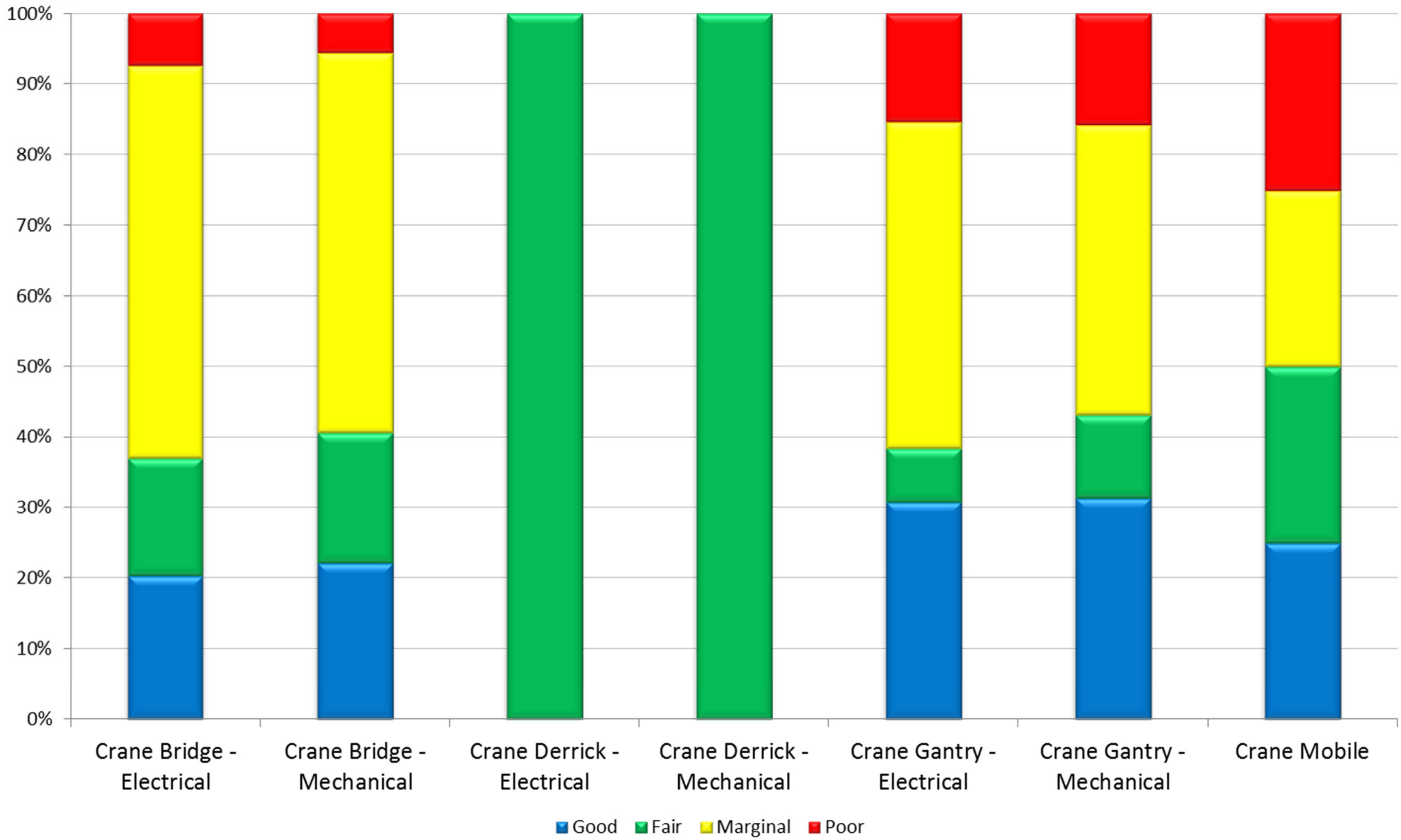
Marginal Resource Cost	$61	$61	$40	$40	$20
Discount Rate	12%	6%	8%	8%	8%
Value of Avoided Carbon Emissions	$35.42/ton	$35.42/ton	$35.42/ton	$0/ton	$0/ton
Budget Constraint	**NPV ($ millions)**	**NPV ($ millions)**	**NPV ($ millions)**	**NPV ($ millions)**	**NPV ($ millions)**
$250M	384	877	332	175	77
$300M	561	1,355	511	291	121
$350M	618	1,405	592	338	151
$400M	646	1,493	632	361	156

APPENDIX C – CONDITION DETAIL

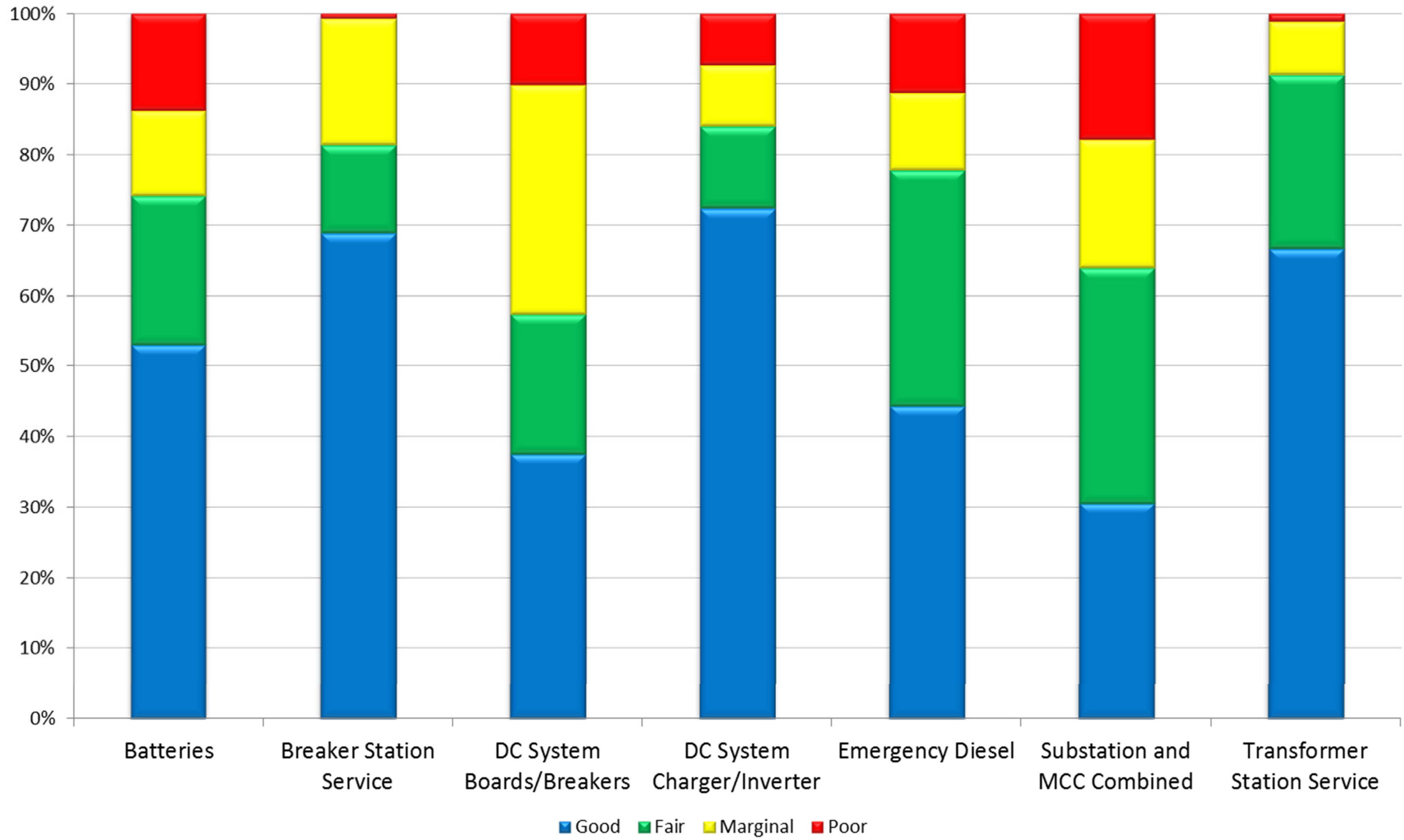
Current Condition: Unit Reliability



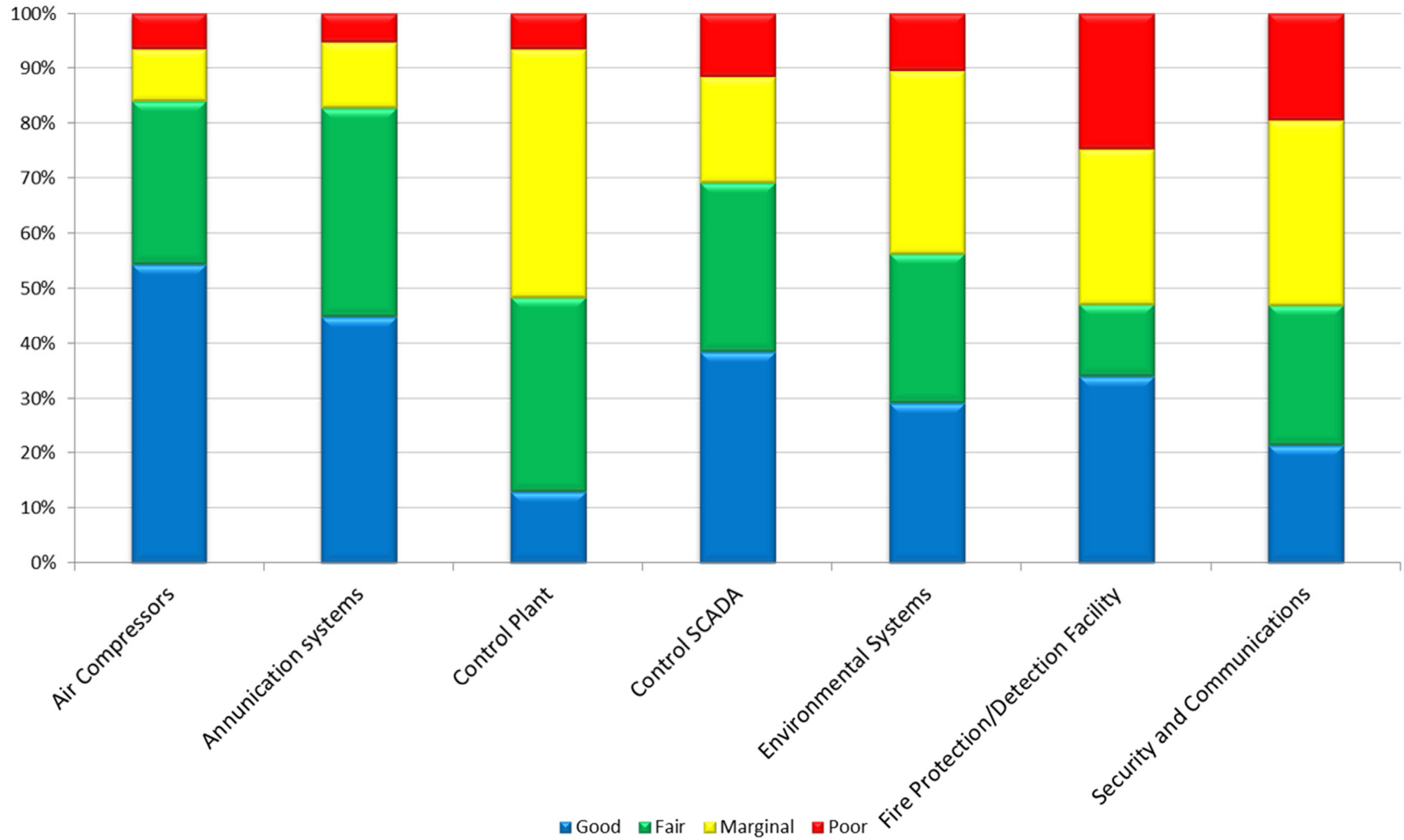
Current Condition: Cranes



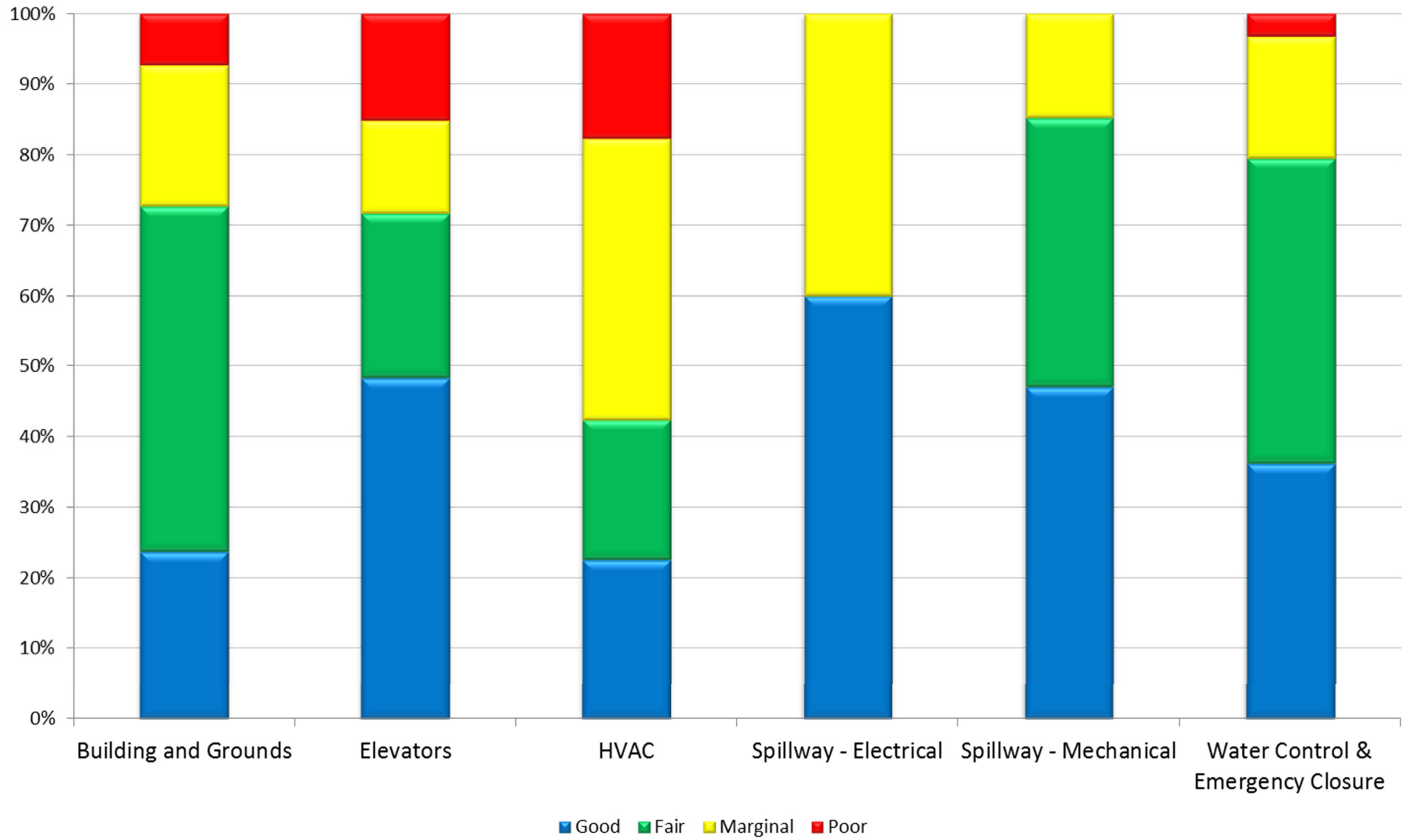
Current Condition: Station Service



Current Condition: Operations Support



Current Condition: Infrastructure and Water Control



Financial Disclosure

This information was made publicly available on June 10, 2016 and contains information not sourced directly from BPA financial statements.